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# DETERMINATION OF FATTY ACIDS IN BUTTER FAT: II [1]

By E. B. HOLLAND, *Associate Chemist*, and MARY E. GARVEY, H. B. PIERCE, ANNE C. MESSER, J. G. ARCHIBALD, and C. O. DUNBAR, *Assistant Chemists, Massachusetts Agricultural Experiment Station*

## INTRODUCTION

Since the publication of an earlier report (7) [2] on the subject, work has been continued under rather adverse conditions due to numerous changes in staff and other unavoidable interruptions. The study of technical methods for fat analysis was undertaken solely for the purpose of evolving some scheme for determining the constituents of butter fat, particularly the different fatty acids, whereby the influence of various physiological factors might be more accurately measured. Sufficient progress having been made in the methods to warrant their application, several experiments were planned with the view of obtaining information relative to the effect of breed, period of lactation, and of different oils and fats in the ration. The aim of each experiment was to determine some distinct phase of the problem, supplemental to the others, and finally to summarize all available data, as indicated by the following synopsis:

I. Composition of butter fat:
   1. From the milk of mixed herd, grade Holsteins and grade Jerseys, fed normal rations.
   2. From the milk of single animals, grade Holsteins and grade Jerseys, comparatively fresh in lactation, fed normal rations.
   3. From the milk of single animals, grade Holsteins and grade Jerseys, fresh, intermediate, and late in lactation, fed normal rations.
   4. From mixed milk of grade Holsteins fed a normal ration with and without the addition of various oils and fats.

II. Summary of data from Massachusetts and elsewhere, together with such general deductions as seem warranted.

It is obvious at the outset that the number of trials will be too small and too limited in scope to furnish even a tithe of the information necessary to a full understanding of the problem, but the authors hope that the investigation may at least throw some light on a difficult subject. All data, both descriptive and analytical, not deemed absolutely essential have been omitted to economize space.

## APPLICATION OF THE METHOD

The cows used in the several experiments herein reported were grade Holsteins and grade Jerseys of the experiment station herd. They were housed in comfortable, well-lighted, and well-ventilated stables

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[2] Reference is made by number (italic) to "Literature cited," pp. 397–398.

and turned out into the yard for several hours every day for exercise, weather permitting. They were fed and milked twice daily, had access to water at all times, and in general received excellent care.

The cream was separated by gravity (Cooley system) and churned as sweet as possible to preserve the several milkings required. The resulting butter fat was melted, filtered, and retained for analysis in glass-stoppered bottles in a partially darkened room.

## I. COMPOSITION OF BUTTER FAT

### 1. FROM THE MILK OF MIXED HERD, GRADE HOLSTEINS AND GRADE JERSEYS, FED NORMAL RATIONS

The analysis given in Tables I and II was published in the earlier article (7), but the percentage of oleic acid has been recalculated from the iodin number of the fat instead of from that of the insoluble acids, and the results are offered as probably typical of butter fat produced by grade animals under the care and feeding practiced at the experiment station. The figures may at least serve as a tentative basis for comparison in the other experiments.

TABLE I.—*Analysis of butter fat*

| | | |
|---|---|---|
| Saponification number ($s$) | (mgm.) | 231.453 |
| Acid number ($a$) | (mgm.) | 2.183 |
| Ether number ($e$) | (mgm.) | 229.270 |
| Iodin number | | 27.999 |
| Equivalent in oleic acid | (per cent) | 31.145 |
| Total fatty acids ($T$) (1.00−0.00022594 $e$) | (per cent) | 94.819 |
| Neutralization number ($n$) $s/T$ | (mgm.) | 244.100 |
| Free fatty acid ($A$) $a/n$ | (per cent) | .894 |
| Soluble fatty acids ($S$) ($T-I$) | (per cent) | 7.319 |
| Neutralization number | (mgm.) | 509.619 |
| Insoluble fatty acids ($I$) by alcoholic potash | (per cent) | 87.500 |
| Neutralization number | (mgm.) | 221.890 |
| Stearic acid (by crystallization) | (per cent) | 13.010 |
| Glycerol (0.00054703 $e$) | (per cent) | 12.542 |

TABLE II.—*Fatty acids in butter fat*

| Fatty acids. | Per cent. |
|---|---|
| Soluble acids: | |
| Butyric acid (by difference) | 3.153 |
| Caproic acid | 1.360 |
| Caprylic acid | .975 |
| Capric acid | 1.831 |
| Total | 7.319 |
| Insoluble acids: | |
| Lauric acid | 6.895 |
| Myristic acid | 22.618 |
| Palmitic acid (by difference) | 15.458 |
| Stearic acid | 11.384 |
| Oleic acid | 31.145 |
| Total | 87.500 |
| Total fatty acids | 94.819 |

As decomposition vitiates certain determinations in the analysis of oils and fats, the results fail to create a perfect entity, but with experienced workers such errors may gradually be reduced to a minimum.

2. FROM THE MILK OF SINGLE ANIMALS, GRADE HOLSTEINS AND GRADE JERSEYS, COMPARATIVELY FRESH IN LACTATION, FED NORMAL RATIONS

The cows in this test were fair types of their respective breeds and comparable in age. Cecile II had freshened more recently than the others. The Holsteins were a high-fat strain of moderate milk yield. The milk produced was the daily average for the period in which cream was saved for churning. The milk analyzed was a five-days' composite, taken about the same time as the cream samples. The feeds, both grain and roughage, were average products of their kind of which analyses were not considered necessary. The results of this test are given in Table III.

TABLE III.—*Records of cows and milk analysis*

| | Colantha II. | Samantha II. | Cecile II. | Peggy. |
|---|---|---|---|---|
| Breed | Grade Holstein | Grade Holstein | Grade Jersey | Grade Jersey. |
| Date of birth | Oct. 14, 1914 | Aug. 18, 1909 | Dec. 18, 1912 | .... 1910. |
| Last calf dropped | July 3, 1917 | Aug. 16, 1917 | Oct. 19, 1917 | Aug. 9, 1917. |
| Condition on calving | Good flesh | Good flesh | Good flesh | Good flesh. |
| Date served | Oct. 22, 1917 | Oct. 26, 1917 | Nov. 24, 1917 | Nov. 8. 1917. |
| Weight of animal | 1,000 pounds | 1,192 pounds | 700 pounds (?) | 780 pounds. |
| Daily ration: | | | | |
| Hay | 18 pounds | 24 pounds | 7 pounds | 17 pounds. |
| Alfalfa | | | 4.5 pounds | |
| Corn stover | | | 16 | |
| Gluten feed | 4 pounds | 4.5 pounds | 3.8 pounds | 3 pounds. |
| Wheat bran | | | 2.5 pounds | |
| Ground oats | 2 pounds | 2.5 pounds | | 1 pound. |
| Corn bran | 4 pounds | 4 pounds | | 4 pounds. |
| Milk produced (daily average).[1] | Oct. 22 to 25, 1917, 23.7 pounds. | Oct. 26 to 29, 1917, 29.7 pounds. | Nov. 5 to 8, 1917, 24.3 pounds. | Oct. 18 to 21, 1917, 17.6 pounds |
| Milk analysis: | | | | |
| Solids (gravimetric) | 13.38 per cent | 12.95 per cent | 14.43 per cent | 15.82 per cent. |
| Fat (Babcock) | 4.40 per cent | 4.55 per cent | 5.40 per cent | 6.60 per cent. |
| Proteids (N × 6.25) | 3.37 per cent | 3.22 per cent | 3.40 per cent | 3.98 per cent. |
| Lactose (by difference) | 4.87 per cent | 4.47 per cent | 4.92 per cent | 4.45 per cent. |
| Ash | .74 per cent | .71 per cent | .71 per cent | .79 per cent. |

[1] For the days cream was saved for churning.

ANALYSIS OF BUTTER FAT

The methods employed for the ordinary analysis of butter fat have been described previously (*8*). The use of glycerol potash for the determination of insoluble acids and the preparation of stock has been superseded, however, by alcoholic potash as less drastic in its action on the unsaturated acids; but even the latter under careful manipulation tends to induce intramolecular changes resulting in a loss of iodin absorption and to some extent an increase in alkali-consuming power due to instability of the resulting molecule, particularly with linolic, linolenic, and other highly unsaturated acids, as shown by Fittig, Varrentrapp, and Schrauth, summarized in another article (*10, p. 362*). Recent experiments, although incomplete, indicate that under control conditions such decomposition can be largely prevented with normal butter fat. The determination of stearic acid by crystallization from alcohol is unquestionably simple in theory but rather difficult in practice except in a cold, dry atmosphere, since condensed moisture is a vitiating factor. The analysis of butter fat is given in Table IV.

TABLE IV.—*Analysis of butter fat*

| | Colantha II. | Samantha II. | Cecile II. | Peggy. |
|---|---|---|---|---|
| Saponification number ($s$).....mgm.. | 229.466 | 230.324 | 230.907 | 230.968 |
| Acid number ($a$).....mgm.. | .927 | 2.386 | 1.626 | 3.657 |
| Ether number ($e$).....mgm.. | 228.539 | 227.938 | 229.281 | 227.311 |
| Iodin number..... | 30.622 | 29.605 | 28.159 | 22.720 |
| Equivalent in oleic acid.....per cent.. | 34.063 | 32.931 | 31.323 | 25.273 |
| Total fatty acids ($T$) (1.00−0.00022594 $e$).....per cent.. | 94.836 | 94.850 | 94.820 | 94.864 |
| Neutralization number ($n$) $s/T$ .....mgm.. | 241.961 | 242.830 | 243.521 | 243.473 |
| Free fatty acids ($A$) $a/n$.....per cent.. | .383 | .983 | .668 | 1.502 |
| Soluble fatty acids ($S$) ($T-I$) .....per cent.. | 6.470 | 7.023 | 7.226 | 6.510 |
| Neutralization number.....mgm.. | 503.184 | 513.356 | 517.409 | 495.637 |
| Insoluble fatty acids ($I$) by alcoholic potash.....per cent.. | 88.366 | 87.827 | 87.594 | 88.354 |
| Neutralization number.....mgm.. | 222.835 | 221.197 | 220.927 | 224.893 |
| Stearic acid by crystallization .....per cent.. | 13.709 | 16.997 | 20.321 | 13.398 |
| Glycerol (0.00054703 $e$).....per cent.. | 12.502 | 12.469 | 12.542 | 12.435 |

The percentages of total fatty acids were 94.843 in the Holsteins and 94.842 in the Jerseys and their neutralization numbers 242.396 and 243.497 mgm., respectively. The percentages of free fatty acids were 0.683 and 1.085, indicating a greater tendency to hydrolyze in the Jerseys. The percentages of soluble fatty acids were 6.747 and 6.868, and their neutralization numbers 508.270 and 506.523. The percentages of insoluble fatty acids were 88.097 and 87.974, and their neutralization numbers 222.016 and 222.910. The nature of these differences is apparent from the data, but the extent can not be actually apportioned with five components involved. The two breeds showed a remarkably close agreement in the several groups of fatty acids and of glycerol, but the proportion of high molecular weight acids in the insolubles was slightly more pronounced in the Holsteins.

The composition of neither breed conformed particularly to that of the herd sample (Table I), although the difference in actual percentage of soluble and of insoluble acids was more appreciable than the difference in proportion of constituent acids in each group, as indicated by the neutralization numbers.

## ESTERIFICATION PROCESS

The method (7) of esterification, purification, and fractionation of the ethyl esters remains substantially as published. Attention might be called, however, to some minor modifications that have since been adopted. Alcohol for esterification is prepared by distilling approximately 2 liters in a water bath over 600 to 700 gm. of granulated caustic lime (95 per cent CaO) and 30 to 40 gm. of yellow ceresin wax and redistilling over fresh lime and ceresin until free from water, as indicated by the absence of lime from solution. On the final distillation the first and last portions are rejected for additional treatment and the main portion is preserved. This process has proved the most reliable so far tested. Three cc. of concentrated sulphuric acid have been substituted as a catalyzer in place of dry hydrochloric acid at a material saving in time and convenience and considerable gain in efficiency.

A second extraction of the alcoholic residue and combined washings with ether is no longer considered necessary. A "high" side tube distillation flask is employed in both the preliminary distillation of the esters and the fractionation. The number of fractions has been increased to 7. Fraction 1, ranging to about 100° C.[3], is the most volatile portion derived from the esters, largely ether but containing considerable ethyl butyrate. It is made to a volume of 500 cc. with ether and the alkali-consuming power of an aliquot is determined; from this the grams of ethyl butyrate can be calculated. Fractions 2 to 6 are now largely determined by weight, a small Troemner scale with prepared counterpoise being used, since the temperature uncorrected and influenced by the speed of distillation has not proved entirely a safe guide. The content of ethyl oleate is no longer considered a prominent factor. By using an adapter on the end of the condenser little difficulty is encountered in changing flasks. The recovery in fractions 2 to 7 has been greatly increased and now averages 185 gm. from 300 gm. of butter fat, with a maximum of 216 gm. thus far.

TABLE V.—*Weight and analysis of fractions (ethyl esters)*

COLANTHA II

| Fraction No. | Range of fraction. | Weight of fraction. | Saponification number. | Iodin number. | Ethyl oleate. |
|---|---|---|---|---|---|
| | °C. | *Gm.* | *Mgm.* | | *Per cent.* |
| 1 | ±70 to 90 | ..... | [a] 1,453.197 | ..... | ..... |
| 2 | 90 to 165 | 5.6093 | 396.205 | 3.776 | 4.618 |
| 3 | 165 to 217 | 3.9590 | 337.924 | 7.241 | 8.854 |
| 4 | 217 to 257 | 6.4436 | 267.689 | 11.872 | 14.518 |
| 5 | 257 to 286 | 13.7516 | 238.602 | 14.216 | 17.384 |
| 6 | 286 to 317 | 57.4804 | 218.942 | 16.275 | 19.902 |
| 7 | 317 to 332 | 97.4166 | 200.959 | 22.324 | 27.299 |
| Total | ..... | 184.6605 | ..... | ..... | ..... |

SAMANTHA II

| | | | | | |
|---|---|---|---|---|---|
| 1 | ±70 to 90 | ..... | [a] 1,655.186 | ..... | ..... |
| 2 | 90 to 166 | 5.5964 | 385.988 | 5.055 | 6.182 |
| 3 | 166 to 218 | 3.9766 | 335.668 | 8.944 | 10.937 |
| 4 | 218 to 258 | 5.4594 | 270.757 | 12.834 | 15.694 |
| 5 | 258 to 286 | 14.2372 | 238.847 | 14.605 | 17.860 |
| 6 | 286 to 317 | 53.7426 | 217.020 | 16.714 | 20.439 |
| 7 | 317 to 327 | 79.3705 | 200.880 | 19.797 | 24.209 |
| Total | ..... | 162.3827 | ..... | ..... | ..... |

CECILE II

| | | | | | |
|---|---|---|---|---|---|
| 1 | ±70 to 100 | ..... | [a] 2,084.412 | ..... | ..... |
| 2 | 100 to 170 | 5.6765 | 405.373 | 2.048 | 2.504 |
| 3 | 170 to 220 | 4.0712 | 357.188 | 3.725 | 4.555 |
| 4 | 220 to 261 | 4.6266 | 287.805 | 7.613 | 9.309 |
| 5 | 261 to 286 | 8.5821 | 249.297 | 10.207 | 12.481 |
| 6 | 286 to 318 | 55.7372 | 218.974 | 14.914 | 18.238 |
| 7 | 318 to 326 | 71.7496 | 204.804 | 19.707 | 24.098 |
| Total | ..... | 150.4432 | ..... | ..... | ..... |

[a] Total alkali-consuming power of the fraction.

[3] With a minimum of 100° C. the complete elimination of ether and alcohol is more definitely assured; otherwise these might vitiate fraction 2.

TABLE V.—*Weight and analysis of fractions*—Continued

PEGGY

| Fraction No. | Range of fraction. | Weight of fraction. | Saponification number. | Iodin number. | Ethyl oleate. |
|---|---|---|---|---|---|
| | °C. | *Gm.* | *Mgm.* | | *Per cent.* |
| 1 | ±70 to 90 | ..... | [a] 1,239.987 | ..... | ..... |
| 2 | 90 to 167 | 4.5351 | 412.882 | 2.279 | 2.787 |
| 3 | 167 to 220 | 4.3029 | 343.102 | 5.383 | 6.583 |
| 4 | 220 to 260 | 5.7014 | 273.896 | 9.093 | 11.119 |
| 5 | 260 to 286 | 14.9828 | 240.286 | 11.265 | 13.775 |
| 6 | 286 to 317 | 54.2113 | 218.762 | 12.135 | 14.839 |
| 7 | 317 to 328.5 | 92.9064 | 203.218 | 14.813 | 18.114 |
| Total | ..... | 176.6399 | ..... | ..... | ..... |

[a] Total alkali-consuming power of the fraction.

TABLE VI.—*Fatty acids in butter fat*

| Fatty acids. | Colantha II. | Samantha II. | Cecile II. | Peggy. |
|---|---|---|---|---|
| Soluble acids: | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Butyric acid (by difference) | 2.260 | 2.928 | 3.007 | 2.726 |
| Caproic acid | 1.588 | 1.688 | 1.794 | 1.290 |
| Caprylic acid | .648 | .744 | .881 | .779 |
| Capric acid | 1.974 | 1.663 | 1.544 | 1.715 |
| Total | 6.470 | 7.023 | 7.226 | 6.510 |
| Insoluble acids: | | | | |
| Lauric acid | 7.618 | 6.317 | 5.616 | 6.598 |
| Myristic acid | 19.768 | 17.455 | 20.534 | 21.782 |
| Palmitic acid (by difference) | 14.803 | 16.196 | 12.321 | 22.863 |
| Stearic acid | 12.114 | 14.928 | 17.800 | 11.838 |
| Oleic acid | 34.063 | 32.931 | 31.323 | 25.273 |
| Total | 88.366 | 87.827 | 87.594 | 88.354 |
| Total fatty acids | 94.836 | 94.850 | 94.820 | 94.864 |

The percentage of butyric acid was 2.594 in the Holsteins and 2.867 in the Jerseys; of caproic acid, 1.638 and 1.542; of caprylic acid, 0.696 and 0.830; and of capric acid, 1.819 and 1.630. The differences were compensating, the high percentages alternating, but were not sufficiently indicative to warrant deductions. The percentage of lauric acid was 6.968 in the Holsteins and 6.107 in the Jerseys; of myristic acid, 18.612 and 21.158; of palmitic acid, 15.500 and 17.592; of stearic acid, 13.521 and 14.819; and of oleic acid, 33.497 and 28.298. The outstanding feature was the low oleic acid content of Peggy's fat, which necessarily affected the results. Despite this fact, however, a lower percentage of myristic and stearic acids and a higher percentage of oleic acid appeared to be characteristic of the Holsteins as contrasted with the Jerseys.

As compared with the herd sample (Table II) neither breed showed any appreciable differences to which attention has not already been called. That the percentage of caproic acid in the herd sample was apparently abnormal, being noticeably lower than is indicated by a subsequent average, is taken into consideration.

3. FROM THE MILK OF SINGLE ANIMALS, GRADE HOLSTEINS AND GRADE JERSEYS, FRESH, INTERMEDIATE, AND LATE IN LACTATION, FED NORMAL RATIONS

The cows were grades, the Jerseys on the average were appreciably older, but all had freshened within a few weeks. Cecile II was the same cow used the year previous. The Holsteins were a 4 per cent strain of fair milk yield. Fancy III, although a high-grade Jersey, did not produce as rich milk as many of that breed.

In the sampling of milk and cream there was an interval of four months [4] between the so-called fresh and intermediate periods of lactation and an additional three months [4] to the late period, during which time the milk yield decreased nearly 32 per cent in the Holsteins and 28 per cent in the Jerseys, and in general the percentages of solids and fat increased but not as consistently as might have been expected.

The same grain mixture and similar hay were fed throughout the different lactation periods, but the amounts varied as stated. Analysis of the hay and various grains indicates their quality (Table X).

TABLE VII.—*Records and analysis of milk from cows fresh in lactation*

| | Colantha. | Samantha IV. | Cecile II. | Fancy III. |
|---|---|---|---|---|
| Breed | Grade Holstein | Grade Holstein | Grade Jersey | Grade Jersey. |
| Date of birth | Nov. 16, 1913 | Aug. 25, 1914 | Dec. 18, 1913 | Aug. 11, 1908. |
| Last calf dropped | Aug. 20, 1918 | Oct. 6, 1918 | Aug. 26, 1918 | Oct. 12, 1918. |
| Condition on calving | Good flesh | Good flesh | Thin | Thin. |
| Date served | Dec. 9, 1918 | Nov. 15, 1918 | Jan. 9, 1919 | Mar. 26, 1919. |
| Weight of animal | 1,195 pounds | 1,113 pounds | 713 pounds | 863 pounds. |
| Daily ration: | | | | |
| Hay | 26 pounds | 24 pounds | 18 pounds | 22 pounds. |
| Grain mixture | 12 pounds. Cottonseed meal, 20 per cent. Gluten feed, 20 per cent, Wheat bran, 30 per cent. Corn feed meal, 30 per cent. | 12 pounds | 8 pounds | 9 pounds. |
| Milk produced (daily average).[1] | Sept. 23 to 26, 1918, 33.5 pounds. | Oct. 31 to Nov. 3, 1918, 41.4 pounds. | Sept. 23 to 27, 1918, 23.7 pounds. | Oct. 31 to Nov. 3, 1918, 33.5 pounds. |
| Milk analysis: | | | | |
| Solids (gravimetric) | 12.47 per cent | 12.80 per cent | 14.43 per cent | 12.50 per cent. |
| Fat (Babcock) | 3.93 per cent | 4.38 per cent | 5.20 per cent | 4.18 per cent. |
| Proteids (N×6.25) | 3.12 per cent | 3.02 per cent | 3.66 per cent | 3.06 per cent. |
| Lactose (by difference) | 4.69 per cent | 4.69 per cent | 4.85 per cent | 4.51 per cent. |
| Ash | .73 per cent | .71 per cent | .72 per cent | .75 per cent. |

[1] For the days cream was saved for churning.

TABLE VIII.—*Records and analysis of milk from cows intermediate in lactation*

| | Colantha. | Samantha IV. | Cecile II. | Fancy III. |
|---|---|---|---|---|
| Weight of animal | 1,280 pounds | 1,163 pounds | 753 pounds | 878 pounds. |
| Daily ration: | | | | |
| Hay | 24 pounds | 22 pounds | 18 pounds | 20 pounds. |
| Grain mixture | 13 pounds | 13 pounds | 8 pounds | 10 pounds. |
| Milk produced (daily average).[1] | Jan. 26 to 29, 1919, 27.9 pounds. | Jan. 30 to Feb. 2, 1919, 33.6 pounds. | Jan. 26 to 29, 1919, 26.7 pounds. | Jan. 30 to Feb. 2, 1919, 29.8 pounds. |
| Milk analysis: | | | | |
| Solids (gravimetric) | 12.84 per cent | 12.66 per cent | 15.52 per cent | 13.00 per cent. |
| Fat (Babcock) | 4.28 per cent | 4.25 per cent | 6.13 per cent | 4.80 per cent. |
| Proteids (N×6.25) | 3.32 per cent | 3.07 per cent | 4.10 per cent | 3.10 per cent. |
| Lactose (by difference) | 4.52 per cent | 4.68 per cent | 4.58 per cent | 4.40 per cent. |
| Ash | .72 per cent | .66 per cent | .71 per cent | .70 per cent. |

[1] For the days cream was saved for churning.

[4] Approximate length of period.

TABLE IX.—*Records and analysis of milk from cows late in lactation*

| | Colantha. | Samantha IV. | Cecile II. | Fancy III. |
|---|---|---|---|---|
| Weight of animal | 1,336 pounds | 1,196 pounds | 730 pounds | 899 pounds. |
| Daily ration: | | | | |
| Hay | 22 pounds | 22 pounds | 16 pounds | 20 pounds. |
| Grain mixture | 13 pounds | 13 pounds | 8 pounds | 10 pounds. |
| Milk produced (daily average).[1] | Apr. 23 to 30, 1919, 23.5 pounds. | Apr. 19 to 25, 1919, 27.7 pounds. | Apr. 19 to 23, 1919, 16.6 pounds. | Apr. 21 to 27, 1919, 25.1 pounds. |
| Milk analysis: | | | | |
| Solids (gravimetric) | 13.45 per cent | 13.12 per cent | 15.07 per cent | 13.00 per cent. |
| Fat (Babcock) | 4.65 per cent | 4.40 per cent | 5.80 per cent | 4.80 per cent. |
| Proteids (N×6.25) | 3.52 per cent | 3.18 per cent | 3.93 per cent | 3.27 per cent. |
| Lactose (by difference) | 4.54 per cent | 4.85 per cent | 4.64 per cent | 4.19 per cent. |
| Ash | .74 per cent | .69 per cent | .70 per cent | .74 per cent. |

[1] For the days cream was saved for churning.

TABLE X.—*Analysis of feeds*

| | Hay. | Cottonseed meal. | Gluten feed. | Wheat bran. | Corn feed meal. |
|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Moisture | 12.35 | 7.50 | 9.32 | 11.90 | 16.70 |
| Dry matter: | | | | | |
| Ash | 6.03 | 6.06 | 4.08 | 6.93 | 1.55 |
| Protein (N×6.25) | 8.09 | 38.51 | 26.77 | 16.44 | 10.31 |
| Fiber | 30.16 | 14.18 | 8.49 | 11.84 | 2.38 |
| Extract matter | 53.07 | 34.10 | 56.81 | 59.31 | 84.27 |
| Fat | 2.65 | 7.15 | 3.85 | 5.48 | 1.49 |

TABLE XI.—*Analysis of butter fat from cows fresh in lactation*

| | Colantha. | Samantha IV. | Cecile II. | Fancy III. |
|---|---|---|---|---|
| Saponification number ($s$) (mgm.) | 232.561 | 233.016 | 232.456 | 235.333 |
| Acid number ($a$) (mgm.) | 2.850 | 1.663 | 1.997 | 2.803 |
| Ether number ($e$) (mgm.) | 229.711 | 231.353 | 230.459 | 232.530 |
| Iodin number | 30.135 | 28.285 | 26.900 | 25.477 |
| Equivalent in oleic acid (per cent) | 33.521 | 31.463 | 29.922 | 28.340 |
| Total fatty acids ($T$) (1.00—0.00022594 $e$) (per cent) | 94.810 | 94.773 | 94.793 | 94.746 |
| Neutralization number ($n$) ($s/T$) (mgm.) | 245.292 | 245.867 | 245.225 | 248.383 |
| Free fatty acids ($A$) $a/n$ (per cent) | 1.162 | .676 | .814 | 1.128 |
| Soluble fatty acids ($S$) ($T-I$) (per cent) | 7.668 | 8.008 | 7.382 | 8.601 |
| Neutralization number (mgm.) | 513.641 | 505.132 | 509.428 | 510.662 |
| Insoluble fatty acids ($I$) by alcoholic potash (per cent) | 87.142 | 86.765 | 87.411 | 86.145 |
| Neutralization number (mgm.) | 221.678 | 221.939 | 222.913 | 222.196 |
| Stearic acid by crystallization (per cent) | 17.399 | 18.669 | 23.304 | 20.991 |
| Glycerol (0.00054703 $e$) (per cent) | 12.566 | 12.656 | 12.607 | 12.720 |

The percentages of total fatty acids were 94.792 in the Holsteins and 94.770 in the Jerseys and their neutralization numbers 245.580 and 246.804 mgm., respectively, indicating a slightly smaller proportion of high molecular weight acids in the Jerseys due to Fancy III's fat. The

percentages of free fatty acids were 0.919 and 0.971. The percentages of soluble fatty acids were 7.838 and 7.992, and their neutralization numbers 509.387 and 510.045, respectively. The percentages of insoluble fatty acids were 86.954 and 86.778, and their neutralization numbers 221.809 and 222.555. The percentage was exceptionally low in Fancy III's fat. The percentages of glycerol were 12.611 and 12.664.

The two breeds contained similar quantities of the several groups of fatty acids and of glycerol, and their acid mixtures, both soluble and insoluble, were of like character, although the neutralization number of the insoluble was slightly higher in the Jerseys.

Both breeds exceeded the herd sample (Table I) materially in soluble fatty acids.

TABLE XII.—*Analysis of butter fat from cows intermediate in lactation*

| | Colantha. | Samantha IV. | Cecile II. | Fancy III. |
|---|---|---|---|---|
| Saponification number ($s$).....(mgm.).. | 229.741 | 229.190 | 231.781 | 234.107 |
| Acid number ($a$).....(mgm.).. | 1.646 | 2.029 | 2.728 | 1.732 |
| Ether number ($e$).....(mgm.).. | 228.095 | 227.161 | 229.053 | 232.375 |
| Iodin number..... | 31.501 | 31.189 | 24.382 | 26.750 |
| Equivalent in oleic acid....(per cent).. | 35.040 | 34.693 | 27.122 | 29.756 |
| Total fatty acids ($T$) (1.00−0.00022594 $e$).....(per cent).. | 94.846 | 94.868 | 94.825 | 94.750 |
| Neutralization number ($n$) ($s/T$).....(mgm.).. | 242.225 | 241.588 | 244.430 | 247.079 |
| Free fatty acids ($A$) $a/n$ (per cent)..... | .680 | .840 | 1.116 | .701 |
| Soluble fatty acids ($S$) ($T-I$) (per cent). | 6.744 | 6.703 | 6.773 | 7.542 |
| Neutralization number.....(mgm.).. | 535.083 | 539.370 | 527.122 | 538.345 |
| Insoluble fatty acids ($I$) by alcoholic potash.....(per cent).. | 88.102 | 88.165 | 88.052 | 87.208 |
| Neutralization number.....(mgm.).. | 219.808 | 218.949 | 222.687 | 221.889 |
| Stearic acid by crystallization.....(per cent).. | 16.923 | 17.732 | 20.493 | 18.287 |
| Glycerol (0.00054703 $e$)....(per cent)... | 12.477 | 12.426 | 12.530 | 12.712 |

The percentages of total fatty acids were 94.857 in the Holsteins and 94.788 in the Jerseys, and their neutralization numbers 241.907 and 245.755 mgm., respectively. The percentages of free fatty acids were 0.760 and 0.908. The percentages of soluble fatty acids were 6.724 and 7.158, and their neutralization numbers 537.227 and 532.734, which were considerably higher than usual. The percentages of insoluble fatty acids were 88.134 in the Holsteins and 87.630 in the Jerseys, and their neutralization numbers 219.379 and 222.288. The percentages of glycerol were 12.452 and 12.621, a noticeable difference.

The Holsteins exceeded the Jerseys in total and insoluble fatty acids and contained a considerably higher proportion of high molecular weight acids in the insolubles. The Jerseys suffered a smaller loss of soluble acids and of glycerol.

The Holsteins exceeded the herd sample (Table I) in insoluble acids with a corresponding loss of soluble acids and a material loss in neutralization number of the insolubles. The Jerseys averaged substantially the same as the herd sample.

TABLE XIII.—*Analysis of butter fat from cows late in lactation*

| | Colantha. | Samantha IV. | Cecile II. | Fancy III. |
|---|---|---|---|---|
| Saponification number ($s$).....(mgm.).. | 224.626 | 225.709 | 230.834 | 231.259 |
| Acid number ($a$).....(mgm.).. | 2.440 | 2.701 | 3.161 | 2.432 |
| Ether number ($e$).....(mgm.).. | 222.186 | 223.008 | 227.673 | 228.827 |
| Iodin number..... | 36.241 | 33.649 | 26.952 | 29.472 |
| Equivalent in oleic acid....(per cent).. | 40.313 | 37.430 | 29.980 | 32.783 |
| Total fatty acids ($T$) (1.00−0.00022594 $e$) .....(per cent).. | 94.980 | 94.961 | 94.856 | 94.830 |
| Neutralization number ($n$) ($s/T$) .....(mgm.).. | 236.498 | 237.686 | 243.352 | 243.867 |
| Free fatty acid ($A$) $a/n$.....(per cent).. | 1.032 | 1.136 | 1.299 | .997 |
| Soluble fatty acids ($S$) ($T-I$) .....(per cent).. | 6.509 | 6.577 | 7.232 | 7.526 |
| Neutralization number.....(mgm.).. | 519.511 | 519.340 | 516.081 | 527.106 |
| Insoluble fatty acids ($I$) by alcoholic potash.....(per cent).. | 88.471 | 88.384 | 87.624 | 87.304 |
| Neutralization number.....(mgm.).. | 215.676 | 216.727 | 220.842 | 219.450 |
| Stearic acid by crystalization .....(per cent).. | 21.628 | 20.399 | 21.033 | 21.512 |
| Glycerol (0.00054703 $e$).....(per cent).. | 12.154 | 12.199 | 12.454 | 12.518 |

The percentages of total fatty acids were 94.971 in the Holsteins and 94.843 in the Jerseys, and their neutralization numbers 237.092 and 243.610 mgm., respectively. The percentages of free fatty acids were 1.084 and 1.148. The percentages of soluble fatty acids were 6.543 and 7.379, and their neutralization numbers 519.426 and 521.594, which were appreciably high. The percentages of insoluble fatty acids were 88.428 and 87.464, and their neutralization numbers 216.202 and 220.146. The percentages of glycerol were 12.177 and 12.486, which was decidedly low in the Holsteins.

The Holsteins further exceeded the Jerseys in total and insoluble fatty acids, with a still greater difference in neutralization number of the insolubles. The Jerseys maintained a high soluble acid content and only a moderate loss of glycerol.

The Holsteins exceeded the herd sample (Table I) in total and insoluble fatty acids by a larger amount than in the previous period and with a greater loss in neutralization number of the insolubles and of glycerol. The Jerseys again averaged practically the same as the herd sample except for an appreciable loss in neutralization number of the insolubles.

TABLE XIV.—*Weight and analysis of fractions of milk from cows fresh in lactation (ethyl esters)*

COLANTHA

| Fraction No. | Range of fraction. | Weight of fraction. | Saponification number. | Iodin number. | Ethyl oleate. |
|---|---|---|---|---|---|
| | °C. | Gm. | Mgm. | | Per cent. |
| 1..... | ±70 to 85 | ..... | [a] 1,472.835 | ..... | ..... |
| 2..... | 85 to 145 | 5.6846 | 398.375 | 2.098 | 2.565 |
| 3..... | 145 to 190 | 5.1990 | 361.366 | 4.514 | 5.520 |
| 4..... | 190 to 230 | 3.8515 | 283.442 | 10.292 | 12.586 |
| 5..... | 230 to 278 | 13.9373 | 242.332 | 14.268 | 17.448 |
| 6..... | 278 to 310 | 57.5422 | 214.019 | 19.080 | 23.331 |
| 7..... | 310 to 328.5 | 128.4525 | 197.332 | 26.687 | 32.634 |
| Total..... | ..... | 214.6671 | ..... | ..... | ..... |

[a] Total alkali-consuming power of the fraction.

TABLE XIV.—*Weight and analysis of fractions of milk from cows fresh in lactation (ethyl esters)*—Continued

SAMANTHA IV (260.1 GM. OF FAT)

| Fraction No. | Range of fraction. | Weight of fraction. | Saponification number. | Iodin number. | Ethyl oleate. |
|---|---|---|---|---|---|
| | °C. | *Gm.* | *Mgm.* | | *Per cent.* |
| 1 | ±70 to 80 | ..... | [a] 1,329.760 | ..... | ..... |
| 2 | 80 to 141 | 4.2115 | 391.789 | 3.229 | 3.948 |
| 3 | 141 to 186 | 4.9620 | 377.169 | 4.997 | 6.111 |
| 4 | 186 to 224 | 3.6875 | 290.948 | 8.754 | 10.705 |
| 5 | 224 to 271 | 10.8334 | 242.858 | 12.122 | 14.823 |
| 6 | 271 to 306 | 45.2200 | 216.148 | 15.072 | 18.430 |
| 7 | 306 to ? | 87.4847 | 199.026 | 20.981 | 25.656 |
| Total | ..... | 156.3991 | ..... | ..... | ..... |

CECILE II (261.96 GM. OF FAT)

| | | | | | |
|---|---|---|---|---|---|
| 1 | ±70 to 80 | ..... | [a] 1,085.690 | ..... | ..... |
| 2 | 80 to 144 | 4.6898 | 397.378 | 2.622 | 3.206 |
| 3 | 144 to 191 | 5.0742 | 345.943 | 4.517 | 5.523 |
| 4 | 191 to 220 | 3.7697 | 279.378 | 7.469 | 9.133 |
| 5 | 220 to 259 | 11.5881 | 242.983 | 10.301 | 12.596 |
| 6 | 259 to 310 | 47.8509 | 214.861 | 14.929 | 18.256 |
| 7 | 310 to 325 | 96.3112 | 197.850 | 21.972 | 26.868 |
| Total | ..... | 169.2839 | ..... | ..... | ..... |

FANCY III

| | | | | | |
|---|---|---|---|---|---|
| 1 | ±70 to 82 | ..... | [a] 1,822.107 | ..... | ..... |
| 2 | 82 to 125 | 5.9548 | 414.095 | 2.389 | 2.921 |
| 3 | 125 to 155 | 5.6521 | 376.234 | 3.962 | 4.845 |
| 4 | 155 to 192 | 4.1875 | 295.894 | 7.721 | 9.441 |
| 5 | 192 to 254 | 13.4642 | 244.204 | 11.283 | 13.797 |
| 6 | 254 to 298 | 55.5961 | 215.916 | 14.377 | 17.581 |
| 7 | 298 to 314 | 104.4243 | 199.966 | 19.299 | 23.599 |
| Total | ..... | 189.2790 | ..... | ..... | ..... |

[a] Total alkali-consuming power of the fraction.

TABLE XV.—*Fatty acids in butter fat from cows fresh in lactation*

| Fatty acids. | Colantha. | Samantha IV. | Cecile II. | Fancy III. |
|---|---|---|---|---|
| Soluble acids: | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Butyric acid (by difference) | 3.179 | ..... | 2.998 | 4.230 |
| Caproic acid | 2.210 | ..... | 1.857 | 2.400 |
| Caprylic acid | .778 | ..... | 1.030 | .714 |
| Capric acid | 1.501 | ..... | 1.497 | 1.257 |
| Total | 7.668 | 8.008 | 7.382 | 8.601 |
| Insoluble acids: | | | | |
| Lauric acid | 4.949 | 4.831 | 4.533 | 4.804 |
| Myristic acid | 20.129 | 18.445 | 19.097 | 20.746 |
| Palmitic acid (by difference) | 13.381 | 15.828 | 13.419 | 14.172 |
| Stearic acid | 15.162 | 16.198 | 20.370 | 18.083 |
| Oleic acid | 33.521 | 31.463 | 29.992 | 28.340 |
| Total | 87.142 | 86.765 | 87.411 | 86.145 |
| Total fatty acids | 94.810 | 94.773 | 94.793 | 94.746 |

The percentage of butyric acid was 3.179 in the Holsteins (1 sample) and 3.614 in the Jerseys; of caproic acid, 2.210 and 2.129; of caprylic acid, 0.778 and 0.872; and of capric acid, 1.501 and 1.377. The differences were not pronounced, but there was a tendency toward a higher content of butyric and caprylic acids in the Jerseys.

The percentage of lauric acid was 4.890 in the Holsteins and 4.669 in the Jerseys; of myristic acid, 19.287 and 19.922; of palmitic acid, 14.605 and 13.796; of stearic acid, 15.680 and 19.227; and of oleic acid, 32.492 and 29.166. The percentage of myristic and stearic acids was lower and that of oleic acid higher in the Holsteins than in the Jerseys.

The soluble acids of the Holsteins were of the same general character as those of the herd sample (Table II), differing somewhat in total but more particularly in the amount of each acid in the mixture, although such differences were largely compensating. This was equally true of the insolubles. In the Jerseys these differences were even more marked than in the Holsteins.

TABLE XVI.—*Weight and analysis of fractions of milk from cows intermediate in lactation (ethyl esters)*

COLANTHA

| Fraction No. | Range of fraction. | Weight of fraction. | Saponification number. | Iodin number. | Ethyl oleate. |
|---|---|---|---|---|---|
| | °C. | Gm. | Mgm. | | Per cent. |
| 1 | ±70 to 80 | ..... | [a] 1,397.089 | ..... | ..... |
| 2 | 80 to 148 | 5.5029 | 392.083 | 3.112 | 3.806 |
| 3 | 148 to 210 | 5.7301 | 350.465 | 6.245 | 7.637 |
| 4 | 210 to 248 | 4.1855 | 273.351 | 11.659 | 14.257 |
| 5 | 248 to 283 | 13.0994 | 238.216 | 15.290 | 18.697 |
| 6 | 283 to 318 | 54.5059 | 214.841 | 18.830 | 23.026 |
| 7 | 318 to 332 | 110.1808 | 198.452 | 25.566 | 31.263 |
| Total | ..... | 193.2046 | ..... | ..... | ..... |

SAMANTHA IV

| | | | | | |
|---|---|---|---|---|---|
| 1 | ±70 to 80 | ..... | [a] 1,383.062 | ..... | ..... |
| 2 | 80 to 139 | 5.4437 | 397.596 | 2.984 | 3.649 |
| 3 | 139 to 195 | 5.6695 | 351.131 | 6.143 | 7.512 |
| 4 | 195 to 235 | 4.3474 | 269.935 | 11.561 | 14.137 |
| 5 | 235 to 275 | 13.3353 | 236.493 | 14.739 | 18.023 |
| 6 | 275 to 315 | 54.8424 | 213.021 | 18.383 | 22.480 |
| 7 | 315 to 329 | 108.1717 | 198.017 | 25.176 | 30.786 |
| Total | ..... | 191.8100 | ..... | ..... | ..... |

CECILE II

| | | | | | |
|---|---|---|---|---|---|
| 1 | ±70 to 80 | ..... | [a] 1,377.451 | ..... | ..... |
| 2 | 80 to 153 | 5.4392 | 390.056 | 2.688 | 3.287 |
| 3 | 153 to 218 | 5.8774 | 340.175 | 4.798 | 5.867 |
| 4 | 218 to 257 | 4.4112 | 273.495 | 8.220 | 10.052 |
| 5 | 257 to 287 | 13.3860 | 240.218 | 10.728 | 13.119 |
| 6 | 287 to 317 | 54.8585 | 216.355 | 13.844 | 16.929 |
| 7 | 317 to 336 | 131.1700 | 198.795 | 20.386 | 24.929 |
| Total | ..... | 215.1423 | ..... | ..... | ..... |

[a] Total alkali-consuming power of the fraction.

TABLE XVI.—*Weight and analysis of fractions of milk from cows intermediate in lactation (ethyl esters)*—Continued

FANCY III

| Fraction No. | Range of fraction. | Weight of fraction. | Saponification number. | Iodin number. | Ethyl oleate. |
|---|---|---|---|---|---|
| | °C. | *Gm.* | *Mgm.* | | *Per cent.* |
| 1 | ±70 to 80 | | [a] 1,500.889 | | |
| 2 | 80 to 132.5 | 5.3816 | 401.690 | 1.797 | 2.197 |
| 3 | 132.5 to 180 | 5.6924 | 364.612 | 3.901 | 4.770 |
| 4 | 180 to 216 | 4.0433 | 291.181 | 8.069 | 9.867 |
| 5 | 216 to 264 | 12.9128 | 245.121 | 12.093 | 14.788 |
| 6 | 264 to 308 | 54.4026 | 216.675 | 15.754 | 19.265 |
| 7 | 308 to 327 | 109.9412 | 200.142 | 21.291 | 26.035 |
| Total | | 192.3739 | | | |

[a] Total alkali-consuming power of the fraction.

TABLE XVII.—*Fatty acids in butter fat from cows intermediate in lactation*

| Fatty acids. | Colantha. | Samantha IV. | Cecile II. | Fancy III. |
|---|---|---|---|---|
| Soluble acids: | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Butyric acid (by difference) | 2.525 | 2.777 | 2.492 | 3.028 |
| Caproic acid | 2.118 | 2.029 | 1.862 | 2.253 |
| Caprylic acid | .763 | .660 | 1.041 | .881 |
| Capric acid | 1.338 | 1.237 | 1.378 | 1.380 |
| Total | 6.744 | 6.703 | 6.773 | 7.542 |
| Insoluble acids: | | | | |
| Lauric acid | 5.409 | 4.534 | 5.403 | 5.272 |
| Myristic acid | 19.188 | 19.624 | 21.287 | 20.763 |
| Palmitic acid (by difference) | 13.555 | 13.681 | 16.196 | 15.469 |
| Stearic acid | 14.910 | 15.633 | 18.044 | 15.948 |
| Oleic acid | 35.040 | 34.693 | 27.122 | 29.756 |
| Total | 88.102 | 88.165 | 88.052 | 87.208 |
| Total fatty acids | 94.846 | 94.868 | 94.825 | 94.750 |

The percentage of butyric acid was 2.651 in the Holsteins and 2.760 in the Jerseys; of caproic acid, 2.074 and 2.058; of caprylic acid, 0.712 and 0.961; and of capric acid, 1.288 and 1.379. In the main the results confirmed those of the previous period as to breed differences.

The percentage of lauric acid was 4.972 in the Holsteins and 5.338 in the Jerseys; of myristic acid, 19.406 and 21.025; of palmitic acid, 13.618 and 15.833; of stearic acid, 15.272 and 16.996; and of oleic acid, 34.867 and 28.439. The breed differences as to myristic and oleic acids were more decisive than in the previous period.

In the Holsteins all the soluble acids decreased in the second period, butyric most of all, and nearly all the insolubles increased, particularly oleic acid, but the agreement with the herd sample (Table II) was not materially improved. In the Jerseys the butyric and caproic acids decreased, and several of the insolubles increased, but stearic and oleic acids decreased, as a whole substantially conforming to the herd sample.

TABLE XVIII.—*Weight and analysis of fractions of milk from cows late in lactation (ethyl esters)*

COLANTHA

| Fraction No. | Range of fraction. | Weight of fraction. | Saponification No. | Iodin No. | Ethyl oleate. |
|---|---|---|---|---|---|
| | °C. | Gm. | Mgm. | | Per cent. |
| 1 | ±70 to 90 | ..... | [a]1, 366. 230 | ..... | ..... |
| 2 | 90 to 146 | 4. 6359 | 400. 958 | 6. 415 | 7. 845 |
| 3 | 146 to 211 | 4. 8609 | 355. 525 | 10. 366 | 12. 676 |
| 4 | 211 to 243 | 4. 1081 | 282. 435 | 14. 466 | 17. 689 |
| 5 | 243 to 283 | 14. 2259 | 244. 859 | 15. 928 | 19. 477 |
| 6 | 283 to 310.5 | 52. 3540 | 220. 233 | 18. 799 | 22. 988 |
| 7 | 310.5 to 331.5 | 67. 4810 | 202. 637 | 23. 845 | 29. 158 |
| Total | ..... | 147. 6658 | ..... | ..... | ..... |

SAMANTHA IV

| | | | | | |
|---|---|---|---|---|---|
| 1 | ±70 to 90 | ..... | [a]1, 371. 841 | ..... | ..... |
| 2 | 90 to 140 | 4. 6752 | 404. 831 | 4. 620 | 5. 650 |
| 3 | 140 to 207 | 4. 8510 | 357. 845 | 8. 077 | 9. 877 |
| 4 | 207 to 244 | 3. 9896 | 285. 900 | 12. 249 | 14. 979 |
| 5 | 244 to 280 | 14. 3177 | 243. 531 | 14. 524 | 17. 761 |
| 6 | 280 to 311 | 52. 8224 | 218. 164 | 17. 529 | 21. 435 |
| 7 | 311 to 326 | 71. 0477 | 202. 061 | 22. 429 | 27. 427 |
| Total | ..... | 151. 7036 | ..... | ..... | ..... |

CECILE II

| | | | | | |
|---|---|---|---|---|---|
| 1 | ±70 to 90 | ..... | [a]1, 357. 814 | ..... | ..... |
| 2 | 90 to 147 | 5. 0608 | 406. 357 | 5. 070 | 6. 200 |
| 3 | 147 to 191 | 5. 3511 | 351. 782 | 7. 401 | 9. 050 |
| 4 | 191 to 231 | 4. 9009 | 282. 018 | 10. 028 | 12. 263 |
| 5 | 231 to 277 | 14. 3388 | 245. 102 | 11. 208 | 13. 706 |
| 6 | 277 to 304 | 52. 3918 | 220. 609 | 13. 141 | 16. 069 |
| 7 | 304 to 321 | 86. 4479 | 202. 460 | 18. 036 | 22. 055 |
| Total | ..... | 168. 4913 | ..... | ..... | ..... |

FANCY III

| | | | | | |
|---|---|---|---|---|---|
| 1 | ±70 to 80 | ..... | [a]1, 402. 700 | ..... | ..... |
| 2 | 80 to 143 | 4. 7724 | 390. 725 | 4. 607 | 5. 634 |
| 3 | 143 to 199 | 5. 3625 | 369. 784 | 6. 796 | 8. 311 |
| 4 | 199 to 235 | 4. 1495 | 289. 912 | 10. 379 | 12. 692 |
| 5 | 235 to 279 | 14. 2308 | 244. 922 | 12. 682 | 15. 508 |
| 6 | 279 to 310 | 53. 1995 | 218. 487 | 15. 436 | 18. 876 |
| 7 | 310 to 327 | 89. 7879 | 200. 926 | 20. 772 | 25. 401 |
| Total | ..... | 171. 5026 | ..... | ..... | ..... |

[a] Total alkali-consuming power of the fraction.

TABLE XIX.—*Fatty acids in butter fat from cows late in lactation*

| Fatty acids. | Colantha. | Samantha IV. | Cecile II. | Fancy III. |
|---|---|---|---|---|
| Soluble acids: | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Butyric acid (by difference) | 2.241 | 2.494 | 2.864 | 3.059 |
| Caproic acid | 1.765 | 1.784 | 1.726 | 2.301 |
| Caprylic acid | .653 | .733 | .857 | .616 |
| Capric acid | 1.850 | 1.566 | 1.785 | 1.550 |
| Total | 6.509 | 6.577 | 7.232 | 7.526 |
| Insoluble acids: | | | | |
| Lauric acid | 7.687 | 6.592 | 7.087 | 6.333 |
| Myristic acid | 15.554 | 17.059 | 18.985 | 18.484 |
| Palmitic acid (by difference) | 5.782 | 9.274 | 13.142 | 10.923 |
| Stearic acid | 19.135 | 18.029 | 18.430 | 18.781 |
| Oleic acid | 40.313 | 37.430 | 29.980 | 32.783 |
| Total | 88.471 | 88.384 | 87.624 | 87.304 |
| Total fatty acids | 94.980 | 94.961 | 94.856 | 94.830 |

The percentage of butyric acid was 2.368 in the Holsteins and 2.962 in the Jerseys; of caproic acid, 1.775 and 2.014; of caprylic acid, 0.693 and 0.737; and of capric acid, 1.708 and 1.668. The breed differences are concealed by the higher content of soluble acids in the Jerseys.

The percentage of lauric acid was 7.140 in the Holsteins and 6.710 in the Jerseys; of myristic acid, 16.307 and 18.735; of palmitic acid, 7.528 and 12.033; of stearic acid, 18.582 and 18.606; and of oleic acid, 38.872 and 31.382. The breed differences were substantially of the same character as in the intermediate period.

The Holsteins differed materially from the herd sample (Table II), particularly in the insoluble acid mixture. In a general way the Jerseys agreed with the herd sample except in stearic acid content.

## EFFECT OF LACTATION

In the Holsteins the percentage of total fatty acids increased 0.065 in four months and 0.179 in seven months, and their neutralization number decreased 3.673 and 8.488 mgm.; the soluble fatty acids decreased 1.114 and 1.295 per cent; the insoluble fatty acids increased 1.180 and 1.474, and their neutralization number decreased 2.430 and 5.607 mgm.; and the glycerol decreased 0.159 and 0.434 per cent. The change in soluble fatty acids consisted of a decreasing loss from butyric acid to caprylic with a slight increase in capric acid. There was an appreciable gain in lauric acid, loss in myristic acid, and marked gain in oleic acid.

In the Jerseys the percentage of total fatty acids increased 0.018 in four months and 0.073 in seven months, and their neutralization number decreased 1.049 and 3.194 mgm.; the soluble fatty acids decreased 0.834 and 0.613 per cent; the insoluble fatty acids increased 0.852 and 0.682 per cent, and their neutralization number decreased 0.267 and 2.409 mgm.; and the glycerol decreased 0.043 and 0.178 per cent. The change in soluble fatty acids was more gradual than in the Holsteins; butyric, caproic, and caprylic acids decreased slightly; capric acid increased; lauric acid increased noticeably; myristic acid decreased; and oleic acid increased, but less than in the Holsteins.

### 4. FROM MIXED MILK OF GRADE HOLSTEINS FED A NORMAL RATION, WITH AND WITHOUT THE ADDITION OF VARIOUS OILS AND FATS

Four grade Holsteins of similar age, comparatively fresh in lactation, were divided into two groups, known as herds A and B. All of the cows, except Samantha III, had been used in previous experiments. The same hay and grain mixture was fed throughout the experiment to both herds, but Colantha was reduced 2 pounds of grain in the last period. Herd B received, in addition, various oils and fats in four periods. The hay and various grains in the mixture were of fair average quality, as shown by analysis (Table XXI). The coconut fat was a refined product said to be used in the manufacture of confectionery, and the peanut and corn oils were refined for salad purposes. The soybean oil was the ordinary commercial product. They were all analyzed (Table XXII) by the common methods but were not esterified.

The milk produced was the daily average for the three days on which cream was saved for churning. The milk analyzed was a five-days' composite taken at substantially the same time as the cream sample.

TABLE XX.—*Records of cows and milk analysis*

| | Herd A. | | Herd B. | |
|---|---|---|---|---|
| | Colantha. | Samantha IV. | Colantha II. | Samantha III. |
| Breed | Grade Holstein | Grade Holstein | Grade Holstein | Grade Holstein |
| Date of birth | Nov. 16, 1913 | Aug. 25, 1914 | Oct. 14, 1914 | Aug. 25, 1913 |
| Last calf dropped | Sept. 19, 1919 | Aug. 20, 1919 | Aug. 8, 1919 | Sept. 12, 1919. |
| Condition on calving | Good flesh | Good flesh | Good flesh | Good flesh. |
| Date served | Dec. 5, 1919; Feb. 4, Mar. 14, 1920. | Dec. 4, 1919 | Nov. 3, 1919 | Dec. 8, 1919. |
| **PERIOD I** | | | | |
| Sample No. | $A_1$ | $A_1$ | $B_1$ | $B_1$ |
| Daily ration: | | | | |
| Hay | 24 pounds | 24 pounds | 22 pounds | 24 pounds. |
| Grain mixture | 10 pounds | 10 pounds | 10 pounds | 10 pounds. |
| Gluten feed, 40 per cent. | | | | |
| Wheat bran, 20 per cent. | | | | |
| Barley meal, 40 per cent. | | | | |
| Weight of animal | 1,348 pounds | 1,160 pounds | 1,093 pounds | 1,210 pounds. |
| Milk produced (daily average),[1] | Nov. 18 to 20, 1919, 29.6 pounds. | Nov. 18 to 20, 1919, 34.7 pounds. | Nov. 18 to 20, 1919, 31.4 pounds | Nov. 18 to 20, 1919, 29.2 pounds. |
| Milk analysis: | | | | |
| Solids (gravimetric) | 12.66 per cent | 12.84 per cent | 13.29 per cent | 13.25 per cent. |
| Fat (Babcock) | 4.23 per cent | 4.50 per cent | 4.60 per cent | 4.58 per cent |
| Proteids (N×6.25) | 3.27 per cent | 3.05 per cent | 3.29 per cent | 3.48 per cent |
| Lactose (by difference) | 4.39 per cent | 4.60 per cent | 4.69 per cent | 4.44 per cent. |
| Ash | .77 per cent | .69 per cent | .71 per cent | .75 per cent. |
| Sample No. | $A_2$ | $A_2$ | $B_2$ | $B_2$ |
| Weight of animal | 1,308 pounds | 1,135 pounds | 1,083 pounds | 1,183 pounds. |
| Milk produced (daily average),[1] | Nov. 27 to 29, 1919, 24.6 pounds. | Nov. 27 to 29, 1919, 31.6 pounds. | Nov. 27 to 29, 1919, 31.0 pounds. | Nov. 27 to 29, 1919, 25.2 pounds. |
| Milk analysis: | | | | |
| Solids (gravimetric) | 12.65 per cent | 12.91 per cent | 13.10 per cent | 13.35 per cent. |
| Fat (Babcock) | 4.43 per cent | 4.50 per cent | 4.38 per cent | 4.48 per cent |
| Proteids (N×6.25) | 3.43 per cent | 3.09 per cent | 3.35 per cent | 3.58 per cent. |
| Lactose (by difference) | 4.00 per cent | 4.63 per cent | 4.64 per cent | 4.54 per cent. |
| Ash | 0.79 per cent | 0.69 per cent | 0.73 per cent | 0.75 per cent. |

[1] For the days cream was saved for churning.

TABLE XX.—*Records of cows and milk analysis*—Continued

PERIOD 2

| | Herd A. | | Herd B. | |
|---|---|---|---|---|
| | Colantha. | Samantha IV. | Colantha II. | Samantha III. |
| Sample No. | $A_2$ | $A_2$ | $B_2$ | $B_2$. |
| Daily ration: | | | | |
| Hay | 24 pounds | 24 pounds | 22 pounds | 24 pounds. |
| Grain mixture | 10 pounds | 10 pounds | 10 pounds | 10 pounds. |
| Coconut fat | | | .75 pounds | .75 pounds. |
| Weight of animal | 1,298 pounds | 1,183 pounds | 1,108 pounds | 1,213 pounds. |
| Milk produced (daily average.)[1] | Dec. 11 to 13, 1919, 18.2 pounds. | Dec. 11 to 13, 1919, 31.5 pounds. | Dec. 11 to 13, 1919, 28.5 pounds. | Dec. 21 to 13, 1919, 25.6 pounds. |
| Milk analysis: | | | | |
| Solids (gravimetric) | 12.66 per cent | 13.04 per cent | 13.81 per cent | 14.12 per cent. |
| Fat (Babcock) | 4.10 per cent | 4.60 per cent | 5.20 per cent | 5.35 per cent. |
| Proteids (N ×6.25) | 3.47 per cent | 3.09 per cent | 3.29 per cent | 3.46 per cent. |
| Lactose (by difference) | 4.29 per cent | 4.65 per cent | 4.59 per cent | 4.54 per cent. |
| Ash | .80 per cent | .70 per cent | .73 per cent | .77 per cent. |
| Sample No. | $A_4$ | $A_4$ | $B_4$ | $B_4$. |
| Weight of animal | 1,333 pounds | 1,203 pounds | 1,123 pounds | 1,255 pounds. |
| Milk produced (daily average).[1] | Dec. 25 to 27, 1919, 23.7 pounds. | Dec. 25 to 27, 1919, 31.6 pounds. | Dec. 25 to 27, 1919, 24.3 pounds. | Dec. 25 to 27, 1919, 24.6 pounds. |
| Milk analysis: | | | | |
| Solids (gravimetric) | 12.96 per cent | 12.87 per cent | 13.31 per cent | 14.20 per cent. |
| Fat (Babcock) | 4.38 per cent | 4.40 per cent | 5.20 per cent | 5.60 per cent. |
| Proteids (N ×6.25) | 3.44 per cent | 3.09 per cent | 3.05 per cent | 3.44 per cent. |
| Lactose (by difference) | 4.35 per cent | 4.68 per cent | 4.35 per cent | 4.40 per cent. |
| Ash | .79 per cent | .70 per cent | .71 per cent | .76 per cent. |

PERIOD 3

| | | | | |
|---|---|---|---|---|
| Sample No. | $A_3$ | $A_3$ | $B_3$ | $B_3$. |
| Daily ration: | | | | |
| Hay | 24 pounds | 24 pounds | 22 pounds | 24 pounds. |
| Grain mixture | 10 pounds | 10 pounds | 10 pounds | 10 pounds. |
| Peanut oil | | | .75 pounds | .75 pounds. |
| Weight of animal | 1,315 pounds | 1,178 pounds | 1,080 pounds | 1,230 pounds. |
| Milk produced (daily average).[1] | Jan. 8 to 10, 1920, 21.8 pounds. | Jan. 8 to 10, 1920, 30.1 pounds. | Jan. 8 to 10, 1920, 33.9 pounds. | Jan. 8 to 10, 1920, 27.7 pounds. |
| Milk analysis: | | | | |
| Solids (gravimetric) | 12.69 per cent | 13.06 per cent | 12.92 per cent | 13.39 per cent. |
| Fat (Babcock) | 4.15 per cent | 4.60 per cent | 4.20 per cent | 4.78 per cent. |
| Proteids (N ×6.25) | 3.47 per cent | 3.12 per cent | 3.22 per cent | 3.29 per cent. |
| Lactose (by difference) | 4.29 per cent | 4.64 per cent | 4.77 per cent | 4.57 per cent. |
| Ash | .78 per cent | .70 per cent | .73 per cent | .75 per cent. |
| Sample No. | $A_5$ | $A_5$ | $B_5$ | $B_5$. |
| Weight of animal | 1,338 pounds | 1,200 pounds | 1,080 pounds | 1,223 pounds. |
| Milk produced (daily average).[1] | Jan. 22 to 24, 1920, 20.8 pounds. | Jan. 22 to 24, 1920, 31.8 pounds. | Jan. 22 to 24, 1920, 33.1 pounds. | Jan. 22 to 24, 1920, 29.9 pounds. |
| Milk analysis: | | | | |
| Solid (gravimetric) | 13.09 per cent | 13.13 per cent | 13.17 per cent | 13.14 per cent. |
| Fat (Babcock) | 4.45 per cent | 4.65 per cent | 4.35 per cent | 4.40 per cent. |
| Proteids (N ×6.25) | 3.51 per cent | 3.17 per cent | 3.31 per cent | 3.34 per cent. |
| Lactose (by difference) | 4.37 per cent | 4.62 per cent | 4.80 per cent | 4.67 per cent. |
| Ash | .76 per cent | .69 per cent | .71 per cent | .73 per cent. |

PERIOD 4

| | | | | |
|---|---|---|---|---|
| Sample No. | $A_7$ | $A_7$ | $B_7$ | $B_7$. |
| Daily ration: | | | | |
| Hay | 24 pounds | 24 pounds | 22 pounds | 24 pounds. |
| Grain mixture | 10 pounds | 10 pounds | 10 pounds | 10 pounds. |
| Corn oil | | | .75 pound | .75 pound. |
| Weight of animal | 1,348 pounds | 1,182 pounds | 1,085 pounds | 1,231 pounds. |
| Milk produced (daily average).[1] | Feb. 5 to 7, 1920, 22 pounds. | Feb. 5 to 7, 1920, 29.6 pounds. | Feb. 5 to 7, 1920, 35.4 pounds. | Feb. 5 to 7, 1920, 31 pounds. |
| Milk analysis: | | | | |
| Solids (gravimetric) | 13.27 per cent | 13.11 per cent | 12.58 per cent | 12.92 per cent. |
| Fat (Babcock) | 4.45 per cent | 4.65 per cent | 4 per cent | 4.33 per cent. |
| Proteids (N×6 25) | 3.58 per cent | 3.16 per cent | 3.14 per cent | 3.26 per cent. |
| Lactose (by difference) | 4.47 per cent | 4.61 per cent | 4.74 per cent | 4.61 per cent. |
| Ash | .77 per cent | .69 per cent | .70 per cent | .72 per cent. |
| Sample No. | $A_8$ | $A_8$ | $B_8$ | $B_8$ |
| Weight of animal | 1,343 pounds | 1,168 pounds | 1,085 pounds | 1,218 pounds. |

[1] For the days cream was saved for churning.

TABLE XX.—*Records of cows and milk analysis*—Continued

PERIOD 4—Continued

| | Herd A. | | Herd B. | |
|---|---|---|---|---|
| | Colantha. | Samantha IV. | Colantha II. | Samantha III. |
| Milk produced (daily average).[1] | Feb. 19 to 21, 1920, 20.6 pounds. | Feb. 19 to 21, 1920, 31.3 pounds. | Feb. 19 to 21, 1920, 33.7 pounds. | Feb. 19 to 21, 1920. 29 pounds. |
| Milk analysis: | | | | |
| Solids (gravimetric) | 13.06 per cent | 12.96 per cent | 12.47 per cent | 12.63 per cent. |
| Fat (Babcock) | 4.40 per cent | 4.50 per cent | 4.00 per cent | 4.20 per cent. |
| Proteids (N×6.25) | 3.45 per cent | 3.14 per cent | 3.09 per cent | 3.08 per cent. |
| Lactose (by difference) | 4.45 per cent | 4.61 per cent | 4.66 per cent | 4.61 per cent. |
| Ash | .76 per cent | .71 per cent | .72 per cent | .74 per cent. |

PERIOD 5

| | | | | |
|---|---|---|---|---|
| Sample No. | $A_9$ | $A_9$ | $B_9$ | $B_9$. |
| Daily ration: | | | | |
| Hay | 24 pounds | 24 pounds | 22 pounds | 24 pounds. |
| Grain mixture | 8 pounds | 10 pounds | 10 pounds | 10 pounds. |
| Soybean oil | | | .75 pounds | .75 pounds. |
| Weight of animal | 1,353 pounds | 1,193 pounds | 1,098 pounds | 1,220 pounds. |
| Milk produced (daily average).[1] | Mar. 4 to 6, 1920, 21.6 pounds. | Mar. 4 to 6, 1920, 29.8 pounds. | Mar. 4 to 6, 1920, 31.8 pounds. | Mar. 6 to 8, 1920, 29.1 pounds. |
| Milk analysis: | | | | |
| Solids (gravimetric) | 12.75 per cent | 13.16 per cent | 12.99 per cent | 12.83 per cent. |
| Fat (Babcock) | 4.25 per cent | 4.60 per cent | 4.20 per cent | 4 per cent. |
| Proteids (N×6.25) | 3.37 per cent | 3.17 per cent | 3.22 per cent | 3.18 per cent |
| Lactose (by difference) | 4.38 per cent | 4.69 per cent | 4.84 per cent | 4.91 per cent. |
| Ash | .75 per cent | .70 per cent | .73 per cent | .74 per cent. |
| Sample No. | $A_{10}$ | $A_{10}$ | $B_{10}$ | $B_{10}$. |
| Weight of animal | 1,345 pounds | 1,170 pounds | 1,088 pounds | 1,245 pounds. |
| Milk produced (daily average).[1] | Mar. 18 to 20, 1920, 22.3 pounds. | Mar. 18 to 20, 1920, 30.1 pounds. | Mar. 18 to 20, 1920, 27.3 pounds. | Mar. 18 to 20, 1920, 27.5 pounds. |
| Milk analysis: | | | | |
| Solids (gravimetric) | 12.95 per cent | 13.30 per cent | 13.79 per cent | 12.91 per cent. |
| Fat (Babcock) | 4.30 per cent | 4.70 per cent | 4.40 per cent | 4.20 per cent. |
| Proteids (N×6.25) | 3.37 per cent | 3.15 per cent | 3.61 per cent | 3.19 per cent. |
| Lactose (by difference) | 4.55 per cent | 4.77 per cent | 5.02 per cent | 4.80 per cent. |
| Ash | .73 per cent | .68 per cent | .76 per cent | .72 per cent. |

[1] For the days cream was saved for churning.

TABLE XXI.—*Analysis of feeds*

| | Hay. | Gluten feed. | Wheat bran. | Barley meal. |
|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Moisture | 10.59 | 10.20 | 12.19 | 12.77 |
| Dry matter: | | | | |
| Ash | 6.03 | 4.52 | 7.31 | 2.45 |
| Protein (N× 6.25) | 8.73 | 27.94 | 16.75 | 12.32 |
| Fiber | 32.38 | 6.32 | 11.29 | 4.86 |
| Extract matter | 50.55 | 58.43 | 59.74 | 77.91 |
| Fat | 2.31 | 2.79 | 4.91 | 2.46 |

TABLE XXII.—*Analysis of oils and fats fed*

| | Coconut fat. | Peanut oil. | Corn oil. | Soybean oil. |
|---|---|---|---|---|
| Saponification number ($s$).....(mgm.).. | 256.600 | 189.835 | 190.761 | 192.337 |
| Acid number ($a$).....(mgm.).. | .092 | .532 | .347 | 2.594 |
| Ether number ($e$).....(mgm.).. | 256.508 | 189.303 | 190.414 | 189.743 |
| Iodin number..... | 9.447 | 94.751 | 123.319 | 131.180 |
| Equivalent in oleic acid....(per cent).. | 10.508 | ..... | ..... | ..... |
| Total fatty acids ($T$) (1.00−0.00022594 $e$) .....(per cent).. | 94.204 | 95.723 | 95.698 | 95.713 |
| Neutralization number($n$)$s/T$ (mgm.).. | 272.388 | 198.317 | 199.336 | 200.952 |
| Free fatty acids ($A$) $a/n$....(per cent).. | .034 | .268 | .174 | 1.291 |
| Soluble fatty acids ($S$) ($T-I$) (per cent).. | 9.372 | None. | None. | None. |
| Neutralization number.....(mgm.).. | 341.539 | ..... | ..... | ..... |
| Insoluble fatty acids ($I$) by alcoholic potash.....(per cent).. | 84.832 | 96.005 | 96.026 | 95.953 |
| Neutralization number.....(mgm.).. | 264.748 | [a] 211.577 | [a] 219.463 | [a] 219.425 |
| Stearic acid by crystallization .....(per cent).. | 2.755 | None. | .523 | .334 |
| Glycerol (0.00054703 $e$).....(per cent).. | 14.032 | 10.355 | 10.416 | 10.380 |
| Refractive index (Abbe) 25° C..... | 1.4550 | 1.4689 | 1.4724 | 1.4737 |
| Refractive index (Abbe) 40° C..... | 1.4491 | 1.4632 | 1.4671 | 1.4677 |
| Colorimeter (Lovibond) ½-inch cell.... | [b] .57 | [b] 1.05 | [b] 2.70 | [b] 16.10 |
| | [c] .03 | [c] .45 | [c] .30 | [c] 3.90 |
| Viscosity (Redwood) 70° F..... | 8.691 | 11.554 | 10.203 | 9.730 |

[a] Exceeds the neutralization number of the total fatty acids due to decomposition difficult to control in such unsaturated products.
[b] Yellow.
[c] Orange.

The composition of the milk (Table XX) produced by the control herd A on hay and grain was fairly constant during the several periods of the experiment (four months), as was also the yield except in the case of Colantha in the second period when there was a noticeable decrease due to a sore teat. The average analysis of the milk of herd A for all periods and that of herd B for each period, together with the yields, are presented in Table XXIII.

TABLE XXIII.—*Summarized milk data*

| | Herd A. | Herd B. | | | | |
|---|---|---|---|---|---|---|
| | Periods 1 to 5. | Period 1, preliminary. | Period 2, coconut fat. | Period 3, peanut oil. | Period 4, corn oil. | Period 5, soybean oil. |
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Solids..... | 12.96 | 13.25 | 13.86 | 13.16 | 12.65 | 13.13 |
| Fat..... | 4.44 | 4.51 | 5.34 | 4.43 | 4.14 | 4.20 |
| Proteids..... | 3.28 | 3.43 | 3.31 | 3.29 | 3.14 | 3.30 |
| Lactose..... | 4.51 | 4.57 | 4.47 | 4.71 | 4.65 | 4.89 |
| Ash..... | .73 | .74 | .74 | .73 | .72 | .74 |
| | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* |
| Average production for the period..... | 27.3 | 29.7 | 25.2 | 31.5 | 32.4 | 29.7 |

There was a substantial agreement in composition of the milk of herd A and that of herd B in the preliminary period, and the yield was similar. It is logical to assume that the composition of the milk of herd B in subsequent periods would have remained fully as constant as that of herd A provided the oils and fats fed were without influence. As compared with the preliminary period, coconut fat increased the solids 0.61 per cent and the fat 0.83 per cent, but at a loss of 4.5 pounds of milk a day for the period. On peanut oil the milk practically reverted to its original composition, with a gain in yield of 1.8 pounds daily over the preliminary period.

By a like comparison, corn oil decreased the solids 0.60 per cent and the fat 0.37 per cent but with an increased yield of 2.7 pounds of milk, and on soybean oil the solids nearly equaled those of the preliminary period, with a loss of 0.31 per cent of fat and approximately the same yield.

### ANALYSIS OF BUTTER FAT FROM HERD A

Colantha and Samantha IV were considered as herd A. The cream from these two cows was mixed and churned, and samples of butter fat were analyzed; but as the maximum range did not exceed a reasonable variation for such a physiological product over a period of four months, three samples, $A_2$, $A_8$, and $A_{10}$ (averaging practically the same as the 10 samples) were deemed sufficient to fully represent the herd and for subsequent esterification.

The percentages of total fatty acids in $A_2$, $A_8$, and $A_{10}$ were 94.771, 94.806, and 94.802 (average 94.793) with no appreciable variation, and their neutralization numbers were 246.212, 244.913, and 243.878 mgm. (average 245.001), with a loss of 2.334 mgm., largely due in advancing lactation to a slight increase of insoluble acids at the expense of the soluble. The percentages of free fatty acids were 0.772, 0.936, and 0.458 (average 0.722), indicating a moderate amount of hydrolysis largely due to manipulation. The percentages of soluble fatty acids were 7.591, 7.302, and 7.258 (average 7.384), and their neutralization numbers 496.614, 491.413, and 498.044 mgm. (average 495.357).

The percentages of insoluble fatty acids were 87.180, 87.504, and 87.544 (average 87.409), and their neutralization numbers 224.409, 224.343, and 222.806 mgm. (average 223.853), indicating a slight increase in the proportion of high molecular weight acids with advancing lactation. The percentages of glycerol were 12.660, 12.576, and 12.586 (average 12.607), indicating no marked change.

As compared with the herd sample (Table I) the average of $A_2$, $A_8$, and $A_{10}$ showed a close agreement in percentage of total, soluble, and insoluble fatty acids and glycerol; but the neutralization number of the total fatty acids was higher by 0.901 mgm., that of the soluble acids was lower by 14.262 mgm., and that of the insoluble acids was higher by 1.963 mgm., indicating some difference in proportion of constituent acids.

TABLE XXIV.—*Analysis of butter fat*

| | Period 1. | | Period 2. | | Period 3. | | Period 4. | | Period 5. | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample No. | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_5$ | $A_6$ | $A_7$ | $A_8$ | $A_9$ | $A_{10}$ |
| Saponification number (*s*) ..... (mgm.) | 233·179 | 233·338 | 230·973 | 232·471 | 232·986 | 232·192 | 231·213 | 231·818 | 231·171 | 231·201 |
| Acid number (*a*) ..... (mgm.) | 1. 661 | 1. 900 | 1. 787 | 1. 933 | 1. 972 | 2. 932 | 1. 474 | 1. 851 | 1. 228 | 1. 118 |
| Ether number (*e*) ..... (mgm.) | 231. 518 | 231. 438 | 229. 186 | 230. 548 | 231. 014 | 229. 260 | 229. 739 | 229. 967 | 229. 943 | 230. 083 |
| Iodin number ..... | 27. 312 | 28. 017 | 28. 831 | 27. 361 | 27. 631 | 27. 853 | 27. 693 | 28. 251 | 28. 294 | 28. 649 |
| Equivalent in oleic acid ..... (per cent) | 30. 381 | 31. 165 | 32. 070 | 30. 435 | 30. 736 | 30. 866 | 30. 847 | 31. 428 | 31. 473 | 31. 868 |
| Total fatty acids (*T*) (1.00—0.00022594 *e*) ..... (per cent) | 94. 769 | 94. 771 | 94. 822 | 94. 791 | 94. 780 | 94. 809 | 94. 804 | 94. 805 | 94. 803 | 94. 802 |
| Neutralization number (*w*) *s*/*T* ..... (mgm.) | 246. 030 | 246. 212 | 243. 586 | 245. 246 | 245. 818 | 244. 913 | 243. 872 | 244. 531 | 243. 838 | 243. 878 |
| Free fatty acids (*A*) *a*/*w* ..... (per cent) | ·675 | ·772 | ·734 | ·784 | ·800 | ·766 | ·604 | ·757 | ·504 | ·458 |
| Soluble fatty acids (*S*) (*T*—*I*) ..... (per cent) | 7. 987 | 7. 591 | 7. 586 | 7. 216 | 7. 167 | 7. 323 | 7. 179 | 7. 196 | 7. 288 | 7. 258 |
| Neutralization number ..... (mgm.) | 462. 927 | 456. 614 | 460. 664 | 456. 656 | 456. 579 | 457. 463 | 457. 330 | 456. 112 | 458. 378 | 458. 044 |
| Insoluble fatty acids (*I*) by alcoholic potash (per cent) | 86. 782 | 87. 180 | 87. 376 | 87. 391 | 87. 413 | 87. 504 | 87. 230 | 87. 208 | 87. 517 | 87. 544 |
| Neutralization number ..... (mgm.) | 216. 089 | 214. 499 | 224. 349 | 214. 262 | 213. 942 | 214. 943 | 213. 241 | 213. 906 | 223. 474 | 222. 806 |
| Stearic acid by crystallization ..... (per cent) | 9. 907 | 10. 345 | 8. 188 | 5. 544 | 6. 503 | 12. 510 | 11. 141 | 11. 346 | 12. 150 | 12. 256 |
| Glycerol (0.00054703 *e*) ..... (per cent) | 12. 665 | 12. 660 | 12. 537 | 12. 622 | 12. 631 | 12. 516 | 12. 567 | 12. 580 | 12. 579 | 12. 586 |
| Refractive index (Abbe) 40° C. ..... | 1. 4536 | 1. 4536 | 1. 4536 | 1. 4536 | 1. 4536 | 1. 4536 | 1. 4536 | 1. 4536 | 1. 4535 | 1. 4534 |
| Colorimeter (Lovibond) ½-inch cell ..... | [a] 3. 20 | [a] 3. 70 | [a] 3. 90 | [a] 3. 00 | [a] 2. 80 | [a] 2. 00 | [a] 2. 10 | [a] 2. 10 | [a] 2. 30 | [a] 2. 20 |
| | [b] 1. 80 | [b] 1. 70 | [b] 1. 50 | [b] 1. 30 | [b] 1. 00 | [b] 1. 00 | [b] 1. 20 | [b] 1. 20 | [b] 1. 20 | [b] 1. 20 |

[a] Yellow. [b] Orange.

TABLE XXV.—*Weight and analysis of fractions (ethyl esters)*

$A_2$

| Fraction No. | Range of fraction. | Weight of fraction. | Saponification number. | Iodin number. | Ethyl oleate. |
|---|---|---|---|---|---|
| | °C. | Gm. | Mgm. | | Per cent. |
| 1 | | | [a] 1,585.051 | | |
| 2 | 90 to 144.5 | 4.7939 | 401.384 | 2.593 | 3.171 |
| 3 | 144.5 to 199 | 5.4274 | 347.415 | 6.021 | 7.362 |
| 4 | 199 to 238 | 5.1062 | 272.158 | 11.306 | 13.825 |
| 5 | 238 to 278.5 | 15.7266 | 238.796 | 14.195 | 17.358 |
| 6 | 278.5 to 310 | 54.5945 | 215.353 | 16.903 | 20.669 |
| 7 | 310 to 325 | 109.4460 | 199.769 | 22.105 | 27.031 |
| Total | | 195.0946 | | | |

$A_6$

| | | | | | |
|---|---|---|---|---|---|
| 1 | ±70 to 90 | | [a] 1,419.532 | | |
| 2 | 90 to 148 | 4.7288 | 398.816 | 2.991 | 3.658 |
| 3 | 148 to 199.5 | 5.1199 | 356.153 | 5.810 | 7.105 |
| 4 | 199.5 to 238.5 | 4.8099 | 281.241 | 10.578 | 12.935 |
| 5 | 238.5 to 281 | 15.7429 | 240.099 | 13.946 | 17.054 |
| 6 | 281 to 312.5 | 53.7111 | 215.163 | 16.509 | 20.187 |
| 7 | 312.5 to 328 | 125.3339 | 198.528 | 22.400 | 27.391 |
| Total | | 209.4465 | | | |

$A_{10}$

| | | | | | |
|---|---|---|---|---|---|
| 1 | ±70 to 90 | | [a] 1,447.586 | | |
| 2 | 90 to 149.5 | 4.6372 | 396.237 | 2.414 | 2.951 |
| 3 | 149.5 to 214 | 5.2042 | 363.557 | 5.083 | 6.216 |
| 4 | 214 to 258.5 | 4.9114 | 274.142 | 11.359 | 13.891 |
| 5 | 258.5 to 294.5 | 15.6960 | 235.719 | 14.710 | 17.988 |
| 6 | 294.5 to 318.5 | 54.0467 | 212.990 | 17.636 | 21.566 |
| 7 | 318.5 to 337 | 128.5638 | 197.798 | 24.760 | 30.277 |
| Total | | 213.0593 | | | |

[a] Total alkali-consuming power of the fraction.

TABLE XXVI.—*Fatty acids in butter fat*

| Fatty acids. | $A_2$. | $A_4$. | $A_{10}$. |
|---|---|---|---|
| Soluble acids: | Per cent. | Per cent. | Per cent. |
| Butyric acid (by difference) | 3.407 | 3.120 | 3.480 |
| Caproic acid | 1.731 | 1.872 | 2.064 |
| Caprylic acid | .810 | .820 | .527 |
| Capric acid | 1.643 | 1.490 | 1.187 |
| Total | 7.591 | 7.302 | 7.258 |
| Insoluble acids: | | | |
| Lauric acid | 5.806 | 5.415 | 4.913 |
| Myristic acid | 20.682 | 20.297 | 20.931 |
| Palmitic acid (by difference) | 20.508 | 22.257 | 19.103 |
| Stearic acid | 9.019 | 8.707 | 10.729 |
| Oleic acid | 31.165 | 30.828 | 31.868 |
| Total | 87.180 | 87.504 | 87.544 |
| Total fatty acids | 94.771 | 94.806 | 94.802 |

The percentages of butyric acid in $A_2$, $A_8$, and $A_{10}$, from cows receiving grain and hay, were 3.407, 3.120, and 3.480 (average 3.336); of caproic acid 1.731, 1.872, and 2.064 (average 1.889); of caprylic acid 0.810, 0.820, and 0.527 (average 0.719); and of capric acid 1.643, 1.490, and 1.187 (average 1.440). The butyric and caproic acids fully maintained their percentage during the four months of the experiment, but the caprylic and capric acids decreased.

As compared with the herd sample (Table II) the butyric acid averaged higher by 0.183 per cent, the caproic acid higher by 0.529 per cent, the caprylic acid lower by 0.256 per cent, and the capric acid lower by 0.391 per cent.

The percentages of lauric acid were 5.806, 5.415, and 4.913 (average 5.378); of the myristic acid 20.682, 20.297, and 20.931 (average 20.637); of the palmitic acid 20.508, 22.257, and 19.103 (average 20.623); of the stearic acid 9.019, 8.707, and 10.729 (average 9.485); and of the oleic acid 31.165, 30.828, and 31.868 (average 31.287). The lauric acid decreased with advancing lactation; otherwise there was no consistent change noted.

As compared with the herd sample (Table II) the lauric acid was low by 1.517 per cent, the myristic acid low by 1.981 per cent, the palmitic acid high by 5.165 per cent, the stearic acid low by 1.899 per cent, and the oleic acid high by 0.142 per cent, a noticeable difference in proportion of constituent acids.

### ANALYSIS OF BUTTER FAT FROM HERD B

Colantha II and Samantha III were considered as herd B. The cream was mixed and churned and 10 samples of butter fat, representing five feeding periods, were analyzed. The first sample in each period was considered indicative, but the second, taken after the same feeding had been continued two weeks longer, was regarded as a better criterion of the effect of the oils and fats fed and consequently for esterification.

Fat samples $B_1$ and $B_2$ were of similar character, differing somewhat in content of soluble fatty acids. As compared with $A_2$, $B_2$ contained practically the same amount of total, free, soluble, and insoluble fatty acids and of glycerol; but the neutralization number of the insoluble acids was slightly higher, 1.174 mgm. It again appears reasonable to assume that, if the feeding of oils and fats was without influence, the composition of the butter fat of herd B should continue fully as uniform as that from herd A, thus permitting a direct comparison of the preliminary $B_2$ and subsequent feeding periods with possibly a slight allowance for advancing lactation.

The soluble fatty acids in $B_4$, from cows receiving coconut fat, decreased 1.243 per cent, as compared with $B_2$; the insoluble fatty acids increased 1.249 per cent and their neutralization number 3.194 mgm., a decided change both in quantity and character of the insoluble acids.

The total fatty acids in $B_6$, from cows receiving peanut oil, increased 0.226 per cent, and their neutralization number decreased 11.213 mgm.; the soluble fatty acids decreased 1.206 per cent, and their neutralization number, 20.055; the insoluble fatty acids increased 1.432 per cent, and their neutralization number decreased 6.983; and the glycerol decreased 0.548 per cent, indicating a notable gain in proportion of higher molecular weight acids in both groups.

TABLE XXVII.—*Analysis of butter fat*

| | Period 1. | | Period 2. | | Period 3. | | Period 4. | | Period 5. | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample number | B 1 | B 2 | B 3 | B 4 | B 5 | B 6 | B 7 | B 8 | B 9 | B 10 |
| Saponification number (*s*) (mgm.) | 232. 634 | 233. 788 | 234. 400 | 233. 234 | 226. 015 | 223. 695 | 223. 857 | 220. 751 | 222. 552 | 221. 622 |
| Acid number (*a*) (mgm.) | 1. 376 | 1. 866 | 1. 693 | 1. 591 | 1. 498 | 1. 786 | 2. 610 | 3. 915 | 1. 759 | 1. 948 |
| Ether number (*e*) (mgm.) | 231. 258 | 231. 922 | 232. 707 | 231. 643 | 224. 517 | 221. 909 | 221. 247 | 216. 836 | 220. 793 | 219. 674 |
| Iodin number | 27. 726 | 27. 663 | 25. 307 | 26. 521 | 36. 248 | 37. 982 | 39. 879 | 40. 423 | 41. 090 | 41. 218 |
| Equivalent in oleic acid (per cent) | 30. 841 | 30. 771 | 28. 150 | 29. 490 | 40. 321 | 42. 250 | 44. 360 | 44. 965 | 45. 707 | 45. 849 |
| Total fatty acids (*T*) (1.00−0.00022594 *e*) (per cent) | 94. 775 | 94. 760 | 94. 742 | 94. 766 | 94. 927 | 94. 986 | 95. 002 | 95. 101 | 95. 011 | 95. 037 |
| Neutralization number (*n*) $s/T$ (mgm.) | 245. 459 | 246. 716 | 247. 408 | 246. 116 | 238. 093 | 235. 503 | 235. 613 | 232. 123 | 234. 238 | 233. 195 |
| Free fatty acids (*A*) $a/n$ (per cent) | . 561 | . 756 | . 684 | . 646 | . 629 | . 758 | 1. 108 | 1. 687 | . 751 | . 835 |
| Soluble fatty acids (*S*) $(T-I)$ (per cent) | 7. 288 | 7. 756 | 7. 276 | 6. 513 | 6. 961 | 6. 550 | 6. 730 | 6. 625 | 6. 271 | 6. 168 |
| Neutralization number (mgm.) | 475. 329 | 483. 780 | 469. 214 | 481. 053 | 475. 980 | 463. 725 | 426. 850 | 418. 506 | 473. 991 | 446. 174 |
| Insoluble fatty acids (*I*) by alcoholic potash (per cent) | 87. 487 | 87. 004 | 87. 466 | 88. 253 | 87. 966 | 88. 436 | 88. 272 | 88. 476 | 88. 740 | 88. 869 |
| Neutralization number (mgm.) | 226. 310 | 225. 583 | 228. 958 | 228. 777 | 219. 269 | 218. 600 | 221. 033 | 218. 167 | 217. 256 | 218. 414 |
| Stearic acid by crystallization (per cent) | 10. 351 | 8. 969 | 10. 971 | 9. 754 | 14. 137 | 14. 716 | 13. 486 | 14. 998 | 14. 418 | 15. 027 |
| Glycerol (0.00054703 *e*) (per cent) | 12. 651 | 12. 687 | 12. 730 | 12. 672 | 12. 282 | 12. 139 | 12. 102 | 11. 862 | 12. 078 | 12. 017 |
| Refractive index (Abbe) 40° C | 1. 4536 | 1. 4536 | 1. 4526 | 1. 4549 | 1. 4551 | 1. 4555 | 1. 4553 | 1. 4553 | 1. 4556 | 1. 4556 |
| Colorimeter (Lovibond) ½-inch cell { | [a] 5. 80 | [a] 5. 70 | [a] 3. 90 | [a] 3. 60 | [a] 2. 25 | [b] 0. 95 | [a] 2. 00 | [a] 2. 10 | [a] 2. 40 | [a] 2. 90 |
| | [b] 1. 70 | [b] 1. 80 | [b] 1. 50 | [b] 1. 25 | [b] 0. 95 | [b] 1. 10 | [b] 1. 40 | [b] 1. 20 | [b] 1. 20 | [b] 1. 50 |

[a] Yellow. [b] Orange.

The total fatty acids in $B_8$, from cows receiving corn oil, increased 0.341 per cent as compared with $B_2$, and their neutralization number decreased 14.593 mgm.; the free fatty acids increased 0.931 per cent; the soluble acids decreased 1.131 per cent, and their neutralization number, 65.274 mgm.; the insoluble acids increased 1.472 per cent, and their neutralization number decreased 7.416 mgm.; and the glycerol decreased 0.825 per cent, a change similar to but more marked than in the previous period.

The total fatty acids in $B_{10}$, from cows receiving soybean oil, increased 0.277 per cent, and their neutralization number decreased 13.521 mgm.; the soluble fatty acids decreased 1.588 per cent, and their neutralization number 37.606 mgm.; the insoluble fatty acids increased 1.865 per cent, and their neutralization number decreased 7.169 mgm.; and the glycerol decreased 0.670 per cent, a change slightly different but approximately the same as in the previous case.

TABLE XXVIII.—*Weight and analysis of fractions (ethyl esters)*

$B_2$

| Fraction No. | Range of fraction. | Weight of fraction. | Saponification number. | Iodin number. | Ethyl oleate. |
|---|---|---|---|---|---|
| | °C. | Gm. | Mgm. | | Per cent. |
| 1 | ±70 to 90 | | [a]1,587.856 | | |
| 2 | 90 to 153 | 4.7042 | 387.750 | 3.158 | 3.862 |
| 3 | 153 to 207 | 5.2264 | 367.367 | 5.541 | 6.776 |
| 4 | 207 to 251 | 4.8993 | 288.957 | 10.324 | 12.625 |
| 5 | 251 to 290.5 | 15.8992 | 245.752 | 13.679 | 16.727 |
| 6 | 290.5 to 316.5 | 53.9656 | 217.611 | 16.639 | 20.347 |
| 7 | 316.5 to 334.5 | 131.8435 | 199.906 | 22.974 | 28.094 |
| Total | | 216.5382 | | | |

$B_4$

| | | | | | |
|---|---|---|---|---|---|
| 1 | ±70 to 90 | | [a]1,441.976 | | |
| 2 | 90 to 138 | 4.4956 | 403.891 | 1.939 | 2.371 |
| 3 | 138 to 201 | 5.0411 | 366.749 | 4.526 | 5.534 |
| 4 | 201 to 245 | 4.8221 | 275.390 | 9.817 | 12.005 |
| 5 | 245 to 274.5 | 15.5843 | 239.613 | 12.513 | 15.301 |
| 6 | 274.5 to 303.5 | 53.5750 | 219.938 | 14.983 | 18.322 |
| 7 | 303.5 to 327.5 | 132.2908 | 202.036 | 22.110 | 27.037 |
| Total | | 215.8089 | | | |

$B_6$

| | | | | | |
|---|---|---|---|---|---|
| 1 | ±70 to 90 | | [a]1,554.192 | | |
| 2 | 90 to 138.5 | 4.6859 | 405.759 | 3.130 | 3.828 |
| 3 | 138.5 to 192 | 5.1400 | 362.188 | 6.403 | 7.830 |
| 4 | 192 to 238 | 4.8029 | 270.068 | 14.655 | 17.921 |
| 5 | 238 to 284 | 15.5928 | 231.380 | 19.448 | 23.782 |
| 6 | 284 to 314 | 53.7289 | 209.791 | 24.451 | 29.900 |
| 7 | 314 to 328 | 103.0110 | 195.994 | 32.311 | 39.511 |
| Total | | 186.9615 | | | |

[a] Total alkali-consuming power of the fraction.

TABLE XXVIII.—*Weight and analysis of fractions*—Continued

$B_9$

| Fraction No. | Range of fraction. | Weight of fraction. | Saponification number. | Iodin number. | Ethyl oleate. |
|---|---|---|---|---|---|
| | °C. | Gm. | Mgm. | | Per cent. |
| 1 | ±70 to 95 | ..... | [a]1,453.197 | ..... | ..... |
| 2 | 95 to 148.5 | 4.4388 | 395.177 | 3.451 | 4.220 |
| 3 | 148.5 to 198 | 4.4753 | 359.884 | 6.806 | 8.323 |
| 4 | 198 to 246 | 4.6266 | 267.181 | 15.492 | 18.944 |
| 5 | 246 to 288 | 14.4314 | 231.499 | 20.229 | 24.737 |
| 6 | 288 to 316.5 | 53.7554 | 209.624 | 25.724 | 31.456 |
| 7 | 316.5 to 333.5 | 99.2487 | 195.484 | 34.729 | 42.468 |
| Total | ..... | 180.9762 | ..... | ..... | ..... |

$B_{10}$

| | | | | | |
|---|---|---|---|---|---|
| 1 | ±70 to 97 | ..... | [a]1,590.662 | ..... | ..... |
| 2 | 97 to 142 | 4.3775 | 402.010 | 4.151 | 5.076 |
| 3 | 142 to 186 | 4.6831 | 360.950 | 7.348 | 8.985 |
| 4 | 186 to 234 | 4.5210 | 271.797 | 15.174 | 18.555 |
| 5 | 234 to 273 | 13.8912 | 231.688 | 20.457 | 25.016 |
| 6 | 273 to 317 | 52.8181 | 210.453 | 25.743 | 31.479 |
| 7 | 317 to 327.5 | 96.9084 | 195.983 | 34.205 | 41.827 |
| Total | ..... | 177.1993 | ..... | ..... | ..... |

[a] Total alkali-consuming power of the fraction.

TABLE XXIX.—*Fatty acids in butter fat*

| Fatty acids, | $B_2$, preliminary. | $B_4$, coconut fat. | $B_6$, peanut oil. | $B_8$, Corn oil. | $B_{12}$, soybean oil. |
|---|---|---|---|---|---|
| Soluble acids: | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. |
| Butyric acid (by difference) | 2.669 | 2.597 | 3.124 | 3.272 | 2.893 |
| Caproic acid | 2.263 | 1.972 | 1.921 | 1.829 | 1.779 |
| Caprylic acid | .816 | .452 | .468 | .401 | .474 |
| Capric acid | 2.008 | 1.492 | 1.037 | 1.123 | 1.022 |
| Total | 7.756 | 6.513 | 6.550 | 6.625 | 6.168 |
| Insoluble acids: | | | | | |
| Lauric acid | 6.210 | 8.042 | 4.681 | 4.551 | 4.839 |
| Myristic acid | 22.050 | 24.988 | 17.223 | 16.428 | 16.128 |
| Palmitic acid (by difference) | 20.170 | 17.125 | 11.268 | [a]9.262 | [a]8.699 |
| Stearic acid | 7.803 | 8.608 | 13.014 | 13.270 | 13.354 |
| Oleic acid | 30.771 | 29.490 | 42.250 | 44.965 | 45.849 |
| Total | 87.004 | 88.253 | 88.436 | 88.476 | 88.869 |
| Total fatty acids | 94.760 | 94.766 | 94.986 | 95.101 | 95.037 |

[a] In these abnormal samples the recovery by distillation exceeded the results reported by 0.698 per cent in $B_8$ and by 0.684 in $B_{12}$. It is impossible to ascribe definitely the source of this error at the present writing.

As compared with $A_2$, $B_2$ on a normal ration contained less butyric acid by 0.738 per cent, more caproic acid by 0.532 per cent, more caprylic acid by 0.006 per cent, and more capric acid by 0.365 per cent, differences too great to permit the direct use of the former as a basis.

In the case of the insoluble acids, $B_2$ contained more lauric acid by 0.404 per cent, more myristic acid by 1.368 per cent, less palmitic acid by 0.338 per cent, less stearic acid by 1.216 per cent, and less oleic acid by 0.394 per cent—a much closer agreement than in the case of the soluble acids, considering the amounts involved, but still making it advisable to use only $B_2$ for direct comparison with the other periods.

As compared with the herd sample (Table II) the differences are even greater. $B_2$ contained less butyric acid by 0.484 per cent, more caproic acid by 0.903 per cent, less caprylic acid by 0.159 per cent, more capric acid by 0.177 per cent, less lauric acid by 0.685 per cent, less myristic acid by 0.568 per cent, more palmitic acid by 4.712 per cent, less stearic acid by 3.581 per cent, and less oleic acid by 0.374 per cent.

The butyric acid in $B_4$, from the cows receiving coconut fat, decreased 0.072 per cent as compared with $B_2$; caproic acid decreased 0.291 per cent; caprylic acid 0.364 per cent; capric acid 0.516 per cent; lauric acid increased 1.832 per cent; myristic acid increased 2.938 per cent; palmitic acid decreased 3.045 per cent; stearic acid increased 0.805 per cent; and oleic acid decreased 1.281 per cent.

As compared with $B_2$, the butyric acid in $B_6$, from cows receiving peanut oil, increased 0.455 per cent; the caproic acid decreased 0.342 per cent; the caprylic acid decreased 0.348 per cent; capric acid decreased 0.971 per cent; lauric acid decreased 1.529 per cent; myristic acid decreased 4.827 per cent; palmitic acid decreased 8.902 per cent; stearic acid increased 5.211 per cent; and oleic acid increased 11.479 per cent.

The butyric acid in $B_8$, from cows receiving corn oil, increased 0.603 per cent as compared with $B_2$; caproic acid decreased 0.434 per cent; caprylic acid decreased 0.415 per cent; capric acid decreased 0.885 per cent; lauric acid decreased 1.659 per cent; myristic acid decreased 5.622 per cent; palmitic acid decreased 10.908 per cent; stearic acid increased 5.467 per cent; and oleic acid increased 14.194 per cent.

As compared with $B_2$, the butyric acid in $B_{10}$, from cows receiving soybean oil increased 0.224 per cent; the caproic acid decreased 0.484 per cent; the caprylic acid decreased 0.342 per cent; the capric acid decreased 0.986 per cent; the lauric acid decreased 1.371 per cent; the myristic acid decreased 5.922 per cent; the palmitic acid decreased 11.471 per cent; the stearic acid increased 5.551 per cent; and the oleic acid increased 15.078 per cent.

In brief, the coconut fat decreased all the soluble acids in increasing amounts from butyric to capric acid, increased the lauric and myristic acids, and decreased the oleic acid.

Peanut oil increased the butyric acid, decreased all the other acids from caproic to palmitic in increasing amounts, and increased stearic and oleic acids materially.

Corn oil increased the butyric acid, decreased all the other acids from caproic to palmitic acid in increasing amounts (except caprylic), and increased the stearic and oleic acids.

Soybean oil increased the butyric acid and decreased all the other acids from caproic to palmitic in increasing amounts (except caprylic), and increased the stearic and oleic acids.

The question naturally arises with butter fats $B_6$, $B_8$, and $B_{10}$, from cows receiving peanut, corn, and soybean oils, as to whether the high iodin numbers might not be due in part to the direct assimilation and transference of linolic and linolenic acids from the oils fed to the butter fat. A number of determinations were made by the lead-salt-ether method with a view of obtaining some definite information on the subject, of which those in Table XXX are fairly typical.

TABLE XXX.—*Lead-salt-ether-soluble fatty acids*

| Sample No. | Fatty acids recovered. | Iodin number. | Neutralization number. |
|---|---|---|---|
| | *Per cent.* | | *Mgm.* |
| $B_8$ | 41.86 | 82.11 | 217.94 |
| $B_{10}$ | 42.55 | 83.02 | 218.27 |

Lead-salt-ether-soluble fatty acids recovered from butter fat are rarely pure liquid acids but are more or less contaminated with small quantities of water-soluble acids extremely difficult to remove by washing and of insoluble saturated acids that pass the filter. The results indicate, however, that with due allowance the liquid acids could not have contained any appreciable quantity of higher unsaturated acids than oleic.

## II. SUMMARY OF DATA FROM MASSACHUSETTS AND ELSEWHERE, TOGETHER WITH SUCH GENERAL DEDUCTIONS AS SEEM WARRANTED

TABLE XXXI.—*Analysis of 29 samples of butter fat from Massachusetts cows fed normal rations*

| | Average. | Range. |
|---|---|---|
| Saponification number ($s$).....(mgm.).. | 231.403 | 224.626 to 235.333 |
| Acid number ($a$).....(mgm.).. | 2.049 | .927 to 3.057 |
| Ether number ($e$).....(mgm.).. | 229.355 | 222.186 to 232.530 |
| Iodin number..... | 28.461 | 22.720 to 36.241 |
| Equivalent in oleic acid.....(per cent).. | 31.315 | 25.273 to 40.313 |
| Total fatty acids ($T$) (1.00−0.00022594 $e$) .....(per cent).. | 94.818 | 94.746 to 94.980 |
| Neutralization number ($n$) $s/T$.....(mgm.).. | 244.051 | 236.498 to 248.383 |
| Free fatty acids ($A$) $a/n$.....(per cent).. | .840 | .383 to 1.502 |
| Soluble fatty acids ($s$) ($T-I$).....(per cent).. | 7.297 | 6.470 to 8.601 |
| Neutralization number.....(mgm.).. | 504.787 | 460.664 to 539.370 |
| Insoluble fatty acids ($I$) by alcoholic potash .....(per cent).. | 87.519 | 86.145 to 88.471 |
| Neutralization number.....(mgm.).. | 222.362 | 215.676 to 226.310 |
| Stearic acid by crystallization....(per cent).. | 15.011 | 5.544 to 23.304 |
| Glycerol (0.00054703 $e$).....(per cent).. | 12.546 | 12.154 to 12.720 |
| Refractive index[1] (Abbe) 40° C..... | 1.4536 | 1.4534 to 1.4536 |
| Colorimeter (Lovibond)[1] ½-inch cell..... | Yellow 3.2<br>Orange 1.4 | Yellow 2.0 to 5.8<br>Orange 1.0 to 1.8 |

[1] Twelve samples.

The 29 samples of butter fat of grade Holsteins and grade Jerseys on normal rations, reported above, contained on the average 94.82 per cent of total fatty acids with a neutralization number of 244; 0.84 per cent of free fatty acids; 7.30 per cent of soluble fatty acids with a neutralization number of 504; 87.52 per cent of insoluble fatty acids with a neutralization number of 222.36; and 12.55 per cent of glycerol. The range in percentage and in neutralization number of both the soluble and insoluble fatty acids was rather pronounced.

TABLE XXXII.—*Fatty acids in 21 samples of butter fat from Massachusetts cows fed normal rations*

| Fatty acids. | Average. | Range. |
|---|---|---|
| | *Per cent.* | *Per cent.* |
| Soluble acids: | | |
| Butyric acid [a] (by difference) | 2.932 | 2.241 to 4.230 |
| Caproic acid [a] | 1.898 | 1.290 to 2.400 |
| Caprylic acid [a] | .786 | .527 to 1.041 |
| Capric acid [a] | 1.570 | 1.187 to 2.008 |
| Total | 7.186 | 6.470 to 8.601 |
| Insoluble acids: | | |
| Lauric acid | 5.849 | 4.533 to 7.687 |
| Myristic acid | 19.784 | 15.554 to 22.618 |
| Palmitic acid (by difference) | 15.167 | 5.782 to 22.863 |
| Stearic acid | 14.907 | 7.803 to 20.370 |
| Oleic acid | 31.895 | 25.273 to 40.313 |
| Total | 87.602 | 86.145 to 88.471 |
| Total fatty acids | 94.788 | 94.746 to 94.980 |

[a] Twenty samples.

The 20 samples of butter fat (analyzed for fatty acids) from cows on normal rations contained on the average 2.93 per cent of butyric acid, 1.90 per cent of caproic acid, 0.79 per cent of caprylic acid, and 1.57 per cent of capric acid. The range in individual acids averaged about 85 per cent, but in most cases the differences were fairly compensating as determined by the neutralization number.

The 21 samples averaged 5.85 per cent of lauric acid, 19.78 per cent of myristic acid, 15.17 per cent of palmitic acid, 14.91 per cent of stearic acid, and 31.90 per cent of oleic acid. The range in lauric, myristic, and oleic acids was less proportionally than in the solubles, in stearic acid somewhat greater, and in palmitic acid almost 300 per cent. As the neutralization number of palmitic acid is nearly that of the average insoluble acid mixture the other four acids were fairly compensating in most instances.

TABLE XXXIII.—*Fatty acids in butter fat*

| | Bell (*1, p. 48*).[1] | Blyth (*2, p. 272*). | Browne (*3, p. 824*). | Crowther and Hynd (*4, p. 145*). | | | Duclaux (*5, p. 1024*). |
|---|---|---|---|---|---|---|---|
| | | | | Dairy butter. | First runnings. | Last runnings. | |
| Soluble acids: | | | | | | | |
| Butyric acid | 6.13 | 3.49 | 5.45 | 4.45 | 4.30 | 4.06 | 3.38 to 3.65 |
| Caproic acid | | 2.40 | 2.09 | 1.45 | 1.98 | 1.48 | 2.00 to 2.26 |
| Caprylic acid | *2.09 | .80 | .49 | .99 | 1.11 | 1.37 | ..... |
| Capric acid | | ..... | .32 | 1.10 | 1.51 | .96 | ..... |
| Total | 8.22 | 6.69 | 8.35 | 7.99 | 8.90 | 7.87 | ..... |
| Insoluble acids: | | | | | | | |
| Lauric acid | ..... | ..... | 2.57 | 3.55 | 5.08 | 6.40 | ..... |
| Myristic acid | | ..... | 9.89 | 20.13 | 10.38 | 18.78 | ..... |
| Palmitic acid | 49.46 | 47.50 | 38.61 | 15.24 | 17.47 | 11.78 | ..... |
| Stearic acid | | ..... | 1.83 | 1.08 | 5.93 | 3.19 | ..... |
| Oleic acid | 36.10 | 40.40 | 32.50 | 45.47 | 46.49 | 41.31 | ..... |
| Di-hydroxy stearic acid | ..... | ..... | 1.00 | .68 | .30 | .16 | ..... |
| Total | 85.56 | 87.90 | 86.40 | 86.15 | 85.65 | 81.62 | ..... |
| Total fatty acids | 93.78 | 94.59 | 94.75 | 94.14 | 94.55 | 89.49 | ..... |

| | Fleischmann and Warmbold (*6, p. 302*). | | | | Jensen (*11, p. 277*). | Koefoed (*12, p. 133*).[2] | Leathes (*14, p. 30*).[3] | Molinari (*17, p. 387*). | Molt (*13*).[4] |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | | | | |
| Soluble acids: | | | | | | | | | |
| Butyric acid | 5.00 | 5.00 | 4.32 | 4.32 | 3.92 | 1.42 | 5.25 to 6.12 | ..... | 7.40 |
| Caproic acid | 2.00 | 2.00 | 2.16 | 2.16 | 1.88 | 1.90 | .90 to 2.70 | ..... | |
| Caprylic acid | .15 | .15 | .67 | .67 | ..... | .47 | Traces. | ..... | |
| Capric acid | ..... | ..... | ..... | ..... | ..... | 1.90 | Traces. | ..... | |
| Total | 7.15 | 7.15 | 7.15 | 7.15 | ..... | 5.69 | ..... | ..... | 7.40 |
| Insoluble acids: | | | | | | | | | |
| Lauric acid | ..... | ..... | ..... | ..... | ..... | 7.58 | Traces. | 14 to 16 | ..... |
| Myristic acid | ..... | ..... | 4.46 | 10.00 | ..... | 20.86 | Traces. | 11 or more. | ..... |
| Palmitic acid | 52.12 | 51.10 | 48.94 | 42.75 | ..... | 26.54 | ..... | 14 to 18 | 20.00 |
| Stearic acid | ..... | 3.35 | 5.54 | 2.00 | ..... | 1.90 | ..... | 7 to 11 | 40.93 |
| Oleic acid | 35.63 | 33.30 | 28.81 | 33.00 | ..... | 32.23 | ..... | 25 to 30 | 26.52 |
| Arachidic acid | ..... | ..... | ..... | ..... | ..... | ..... | Traces. | ..... | ..... |
| Higher unsaturated acids | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 4 to 5.7 | ..... |
| Total | 87.75 | 87.75 | 87.75 | 87.75 | ..... | 89.11 | ..... | ..... | 87.45 |
| Total fatty acids | 94.90 | 94.90 | 94.90 | 94.90 | ..... | 94.80 | ..... | ..... | 94.85 |

[1] Reference is made by number (italic) to "Literature cited," pp. 397–398.
[2] Results recalculated on a basis of 94.80 per cent total fatty acids.
[3] Recalculated.
[4] Results recalculated by Browne.

TABLE XXXIII—*Fatty acids in butter fat*—Continued

| | Partheil and Ferie (*18, p. 506*). | | Richmond (*19, p. 42*). | Siegfeld (*20, p. 202, 204, 205*). | | | | Smedley (*21, p. 457*). | Spallazini (*22, p. 808*).[1] |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 | | |
| **Soluble acids:** | | | | | | | | | |
| Butyric acid | | | 3.43 | 3.53 | 3.58 | 3.27 | 3.35 | | 4.44 |
| Caproic acid | | | 3.25 | 1.50 | 1.26 | 1.73 | 1.68 | | .92 |
| Caprylic acid | | | .51 | 1.03 | 2.87 | 1.89 | 2.21 | | .28 |
| Capric acid | | | 1.77 | | | | | | |
| Total | | | 8.96 | 7.06 | 7.72 | 6.89 | 7.24 | | 5.64 |
| **Insoluble acids:** | | | | | | | | | |
| Lauric acid | 16.40 | 14.88 | 6.94 | | | | | | |
| Myristic acid | 11.09 | 11.88 | 19.14 | 25.35 | 22.94 | 30.70 | 26.00 | | |
| Palmitic acid | 18.24 | 14.46 | 24.48 | 17.18 | 20.84 | 16.89 | 20.96 | | 89.48 |
| Stearic acid | 6.65 | 10.49 | 1.72 | | | | | 10–15 | |
| Oleic acid | 30.67 | 32.64 | 33.60 | 42.75 | 40.53 | 37.98 | 38.09 | | |
| Higher unsaturated acids | 5.40 | 4.15 | | | | | | | |
| Total | 88.45 | 88.50 | 85.88 | 85.28 | 84.31 | 85.57 | 85.05 | | 89.48 |
| Total fatty acids | | | 94.84 | 92.34 | 92.09 | 92.46 | 92.29 | | 95.12 |

| | Violette (*23, p. 346*). | | | | | | | | Wright (*24, p. 14*).[1] |
|---|---|---|---|---|---|---|---|---|---|
| | Superior qualities of butter. | | | Inferior qualities of butter. | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| **Soluble acids:** | | | | | | | | | |
| Butyric acid | 6.07 | 5.33 | 5.50 | 5.05 | 4.62 | 4.80 | 4.76 | 4.37 | 5.25 |
| Caproic acid | 3.66 | 3.23 | 3.34 | 3.06 | 2.80 | 2.92 | 2.89 | 2.65 | |
| Capric acid | 2.85 | 3.00 | 2.80 | 3.00 | 2.90 | 2.40 | 3.00 | 2.95 | |
| Total | 12.58 | 11.56 | 11.64 | 11.11 | 10.32 | 10.12 | 10.65 | 9.97 | |
| **Insoluble acids:** | | | | | | | | | |
| Lauric acid | | | | | | | | | |
| Myristic acid | | | | | | | | | |
| Palmitic acid | 82.28 | 82.63 | 82.87 | 83.20 | 84.32 | 84.31 | 83.83 | 84.62 | |
| Stearic acid | | | | | | | | | |
| Oleic acid | | | | | | | | | |
| Total | 82.28 | 82.63 | 82.87 | 83.20 | 84.32 | 84.31 | 83.83 | 84.62 | |
| Total fatty acids | 94.86 | 94.19 | 94.51 | 94.31 | 94.64 | 94.43 | 94.48 | 94.59 | |

[1] Recalculated.

The results of other workers and compilers showed noticeable variations in total, soluble, and insoluble fatty acids (affected no doubt by the method of analysis, as well as by difference in product), but after the elimination of extremes they agreed as to the general character of butter fat better than might be expected. Although any deductions are open to criticism, the results appeared to indicate a total fatty acid content of approximately 94.41 to 94.90 per cent, soluble acids 6.69 to 8.96 per cent, and insoluble acids 86.15 to 88.50 per cent. These figures do not differ materially from those secured on Massachusetts samples.

The percentage of the different soluble fatty acids by other investigators showed decided variations. The results, while not strictly comparable, recognized butyric acid as the most prominent, with caproic acid second. The data for caprylic and capric acids were quite limited. In a few instances caprylic acid was shown to be the smallest constituent,

but in no case did both caprylic and capric acids agree with the average of the samples tested in Massachusetts.

Of the insolubles, lauric acid was seemingly at least one of the smaller and myristic acid one of the larger ingredients, but only in a few cases were the results at all consistent. The range in palmitic acid was rather wide, but on excluding the higher percentages most of the remainder were between 15 and 25 per cent.

In stearic-acid content there was again considerable divergence. The results may be divided into two groups from 1.08 to 3.35 per cent and from 5.54 to 15 per cent. Of the more recent workers Miss Smedley obtained a higher percentage than the others. The Massachusetts average herein reported on normal rations is somewhat higher than previously secured (*9, p. 109–110*) and may prove higher than subsequent figures from a greater number of cows will justify.

The percentage of oleic acid varied from 25 to 46.49. A number of the foreign butter fats had an oleic-acid content similar to those derived in Massachusetts from feeding corn and soybean oils. This acid appears to respond the most readily to the influences of feed and advancement in lactation.

The small quantity of di-hydroxy stearic acid reported in butter fat may arise from decomposition changes accompanying analytical procedure rather than as a natural occurrence. The weight of evidence does not support the contention that unsaturated acids higher than oleic are present in straight butter fat to any appreciable amount.

## GENERAL CONCLUSIONS

(1) On normal rations the percentage of total fatty acids in the butter fat of the Holsteins was substantially the same as that of the Jerseys, but their neutralization number was somewhat lower; the free fatty acids and soluble fatty acids were also lower, while the percentage of insoluble fatty acids was higher and their neutralization number and glycerol lower.

(2) The percentages of butyric and caprylic acids were lower in the Holsteins than in the Jerseys; caproic and capric acids higher; lauric and oleic acids higher; and myristic, palmitic, and stearic acids lower.

(3) With advancing lactation the percentages of total fatty acids increased slightly in both breeds, while their neutralization numbers decreased; the soluble fatty acids decreased, while the insoluble fatty acids increased and their neutralization numbers and the glycerol decreased. As a rule the changes were more pronounced in the Holsteins.

(4) The addition of oils and fats to the normal rations increased the insoluble fatty acids, partly at the expense of the solubles and partly by increasing the total fatty acids, and in consequence depressed the glycerol content.

(5) The neutralization numbers of the soluble, insoluble, and total fatty acids were decreased on feeding the peanut, corn, and soybean oils, and that of the insoluble acids was increased by coconut fat.

(6) Of the soluble acids, butyric fluctuated but maintained its percentage, caproic acid decreased appreciably, and caprylic and capric acids decreased about 50 per cent in extreme cases. Of the insoluble acids, lauric and myristic acids increased when coconut fat was fed but decreased when unsaturated oils were fed. In the latter cases oleic acid increased greatly.

(7) In so far as it is possible to draw a general conclusion from the data thus far secured from all experiments (*15*, *16*) made at this station extending over many years, it seems evident that neither protein nor carbohydrates have any appreciable influence in changing the chemical composition of the butter fat; on the other hand, different oils and fats do modify to an extent the chemical composition of butter fat, the modification depending upon the composition of the oils and fats fed.

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# STRIPED SOD WEBWORM, CRAMBUS MUTABILIS CLEMENS[1]

By GEORGE G. AINSLIE

*Entomological Assistant, Cereal and Forage Insect Investigations, Bureau of Entomology, United States Department of Agriculture*

## INTRODUCTION

Throughout a wide area *Crambus mutabilis* is one of the most common species of the genus. It ranks well toward the head of the list in destructiveness, although by itself it never has been directly charged with a destructive outbreak. It has not previously received detailed study, and the available information concerning it is scattered and meager. The present paper includes a summary of previously published facts, together with the results of the writer's studies for several years.

## SYSTEMATIC HISTORY

*Crambus mutabilis* was first described by Clemens (*3, p. 204*)[2] in 1860, but he furnished no information as to the source of his material. Three years later Zeller (*15, p. 44*) redescribed it as *Crambus fuscicostellus*, a name which better characterizes the species than Clemens's adjective. Both names appear in the literature for some years, although Grote (*7, p. 79*) early recognized their probable synonymy. Smith (*13, p. 87*) first placed *fuscicostellus* unconditionally as a synonym of *mutabilis*, in which he is fully borne out by Hampson (*8, p. 928*), who had Zeller's type in the British Museum for comparison.

## GEOGRAPHICAL DISTRIBUTION

*Crambus mutabilis* seems to be a purely North American species, for outside of North America it has been reported only by Hedemann (*9, p. 300*), from St. Thomas Island in the West Indies. It is widespread over the eastern half of the United States. A study of the published records and of all the available museum material shows that the outlying points from which reliable records are available are Brownsville and Amarillo, Tex.; Vineyard, Utah; Sioux City, Iowa; and Cartwright, Manitoba. It has been found in most of the States to the eastward of a line connecting these places, although it does not appear in a considerable collection of the genus made in southern Minnesota, and has not been recorded from Wisconsin, West Virginia, and several of the New England States.

The reported occurrence in Nebraska is evidently based on Bruner's paper (*2, p. 262*), in which, however, he does not say that it has been taken in that State. It has been taken at numerous points in Florida, but, except for a single specimen from northwestern Arkansas, has not yet been reported from the tier of States between and including Oklahoma

[1] Accepted for publication July 11, 1922. This paper is the third in a series of Contributions to a Knowledge of the Crambinæ of North America. I, *Crambus hemiochrellus* Zeller, appeared in Annals of the Entomological Society of America for March, 1918, and II, *Crambus laqueatellus* Clemens, in the June, 1922, issue of the same journal.

[2] Reference is made by number (italic) to "Literature cited," p. 414.

and South Carolina, although it probably occurs throughout that section. There is a specimen in Doctor Barnes's collection from Digby, Nova Scotia. It has also been reported from California in a broad way, by various writers following Felt (*4, p. 97*), but the writer has seen nothing to substantiate this record. There is a single specimen in the National Museum labeled "Arizona," from Riley's collection. The accompanying map (fig. 1) shows the points in the United States whence definite records have been obtained. Where no exact locality is given the State is marked with an interrogation point.

## FOOD PLANTS

The striped sod webworm has never been recorded as feeding on any plant outside the grass family. In the field, larvæ have been taken on blue grass, corn, wheat, timothy, and once, at Nashville, Tenn., on small clumps of a wild grass which was not at the time in determinable con-

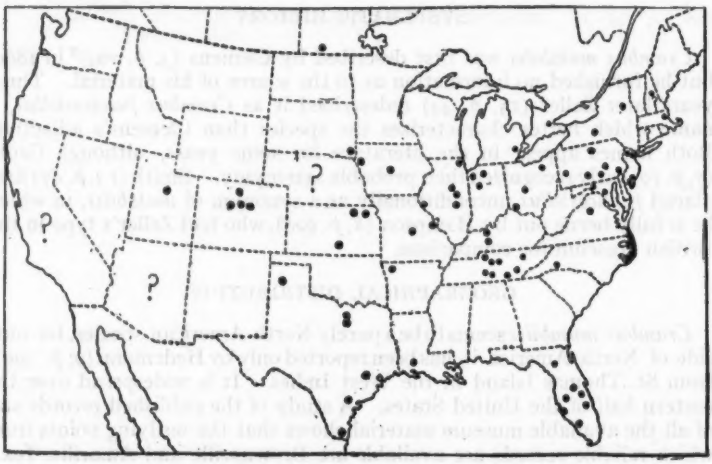


FIG. 1.—Map showing known distribution of *Crambus mutabilis* in North America.

dition. In addition to the foregoing the writer has reared it in cages on crab grass (*Syntherisma sanguinalis*), barley, and rye. Larvæ were also offered oats and orchard grass (*Dactylis glomeratus*) and in the later stages fed freely. The young larvæ, however, seemed to have trouble in subsisting on these grasses, and none were reared on them alone. Undoubtedly the larvæ will thrive on many other grasses.

## ECONOMIC HISTORY

Few cases of serious injury are definitely chargeable to *Crambus mutabilis*. This does not mean that it is not an injurious form, but merely that it has not been caught in the act. There is plenty of circumstantial evidence to warrant an indictment aside from the established records. Bruner (*2, p. 262*) first mentions it as a grass insect attacking corn following sod. Riley (*11, p. 36*) says it occasionally attacks corn. Webster (*14, p. 86*) intimates that this species may have had something to do with the destruction wrought in meadows and in

corn and oat fields in northern Ohio in 1895 by his statement that the moths were taken in June following the outbreak, but "in more limited numbers" than those of *C. trisectus*, to which the larger part of the trouble was undoubtedly due. From Forbes (*6, p. 39–42*) there are numerous reports of crambid injuries, especially to corn, but in not a single instance does he attribute the damage to this species alone; always at least one other species is involved.

In the writer's experience larvæ have been found in numerous instances destroying corn plants, and almost invariably either the crop followed sod or the injury was confined to the margin of the field. At Spring Hill, Tenn., one larva was found destroying a wheat plant early in June. A. F. Satterthwait has on three occasions sent the writer larvæ found feeding in the bulbs of timothy plants. In some experimental plantings of corn on sod land near Chapel Hill, Tenn., three of these larvæ were found to every one of *Crambus caliginosellus*, the only other crambid present, and the stand of corn was being very materially injured by them. In 1920, near La Fayette, Ind., this species, associated with *C. trisectus*, caused severe injury in several fields of corn.

Although there is no record of a general outbreak of this species, it is certain that, with favoring conditions, severe but narrowly local outbreaks occur more often than is realized. The moths are often sufficiently numerous to show that a large amount of food has been required to produce them, and as the larvæ seem to be strictly grass feeders the species must be placed well toward the head of the list of injurious forms. It seems especially subject to parasitism and epidemic diseases, and this may explain why it has not increased to such an injurious degree as some of the other species.

## SEASONAL HISTORY

In Tennessee, where collections have been constantly made for the last five years, the moths first appear about May 15, the date of their appearance being very uniform year after year. By May 20 they are abundant and continue so for a month in gradually decreasing numbers. During five years' collecting no moths have been taken between June 19 and July 3, and only scattering individuals until about July 10, when the moths of the second generation appear in greater numbers and remain over a longer period than those of the first generation, continuing fairly abundant until August 15. Then after another interval of absence a few appear during the last few days of August and in September, evidently a partial third generation. The latest record for the country is of one moth taken at Knoxville, Tenn., October 26, long after the others were gone.

In Florida, the moths of the first generation appear as early as the latter half of February, but data are lacking for the rest of the year. A fairly complete series of collections made at La Fayette, Ind., shows that in that latitude the periods of abundance fall about a month later than in Tennessee, the first from June 20 to July 10 and the second from August 6 to September 8. Even there the partial third generation appears, as moths were taken October 1 and 2 after having been absent for nearly a month. The La Fayette records accord closely with Forbes's (*6, p. 43*) statement for Illinois—

> two well-marked periods of maximum occurrence, one in July and one in August, with a comparatively sparse showing toward the middle of July.

Both Felt (*4, p. 65*) and Slingerland (*12, p. 210*) report the results of trap lantern collections at Ithaca, N. Y., and, although the number of moths taken is too small to more than indicate the facts, they seem to show that the two periods of greatest abundance lie between June 10 and 20 and July 8 and 20. More than one month is required for the development of a generation, so these Ithaca figures must be taken subject to revision.

## REARING RECORDS

Laboratory records fully bear out the foregoing observations. Table I is a compilation of all the rearing records available for individuals under observation from egg to adult. It will be noticed that during the summer the interval between oviposition and the emergence of the adult is from 42 to 70 days, averaging about 55 days. Allowing three days for the preoviposition period brings it to 58 days, slightly less than two months from egg to egg. This works out almost exactly in the table; one generation from May 23 to July 21; the second from July 21 to September 11; and the third, or overwintering generation, from September 11 to the following May. It will be noted also that many of the later larvæ of the second generation, those coming from eggs laid after August 1, emerged the following spring. Thus it is safe to conclude that in Tennessee there are normally three generations per year, some of the second and all of the third overwintering as larvæ. Farther north the third doubtless becomes smaller and may completely disappear, leaving larvæ of only the second generation to pass the winter.

TABLE I.—*Rearing records of Crambus mutabilis under observation in the laboratory or insectary from egg to adult*[1]

| Cage No. | Eggs laid. | Moth out. | Number of days. | Sex. | Number of moths. |
|---|---|---|---|---|---|
| A | May 23 | July 8 | 46 | ♂ | 1 |
| A | 23 | Aug. 5 | 74 | ♂ | 1 |
| 1775 | 23 | July 30 | 68 | ♂ | 1 |
| 1775 | 23 | Aug. 2 | 71 | ♀ | 1 |
| B | 26 | July 7 | 42 | ♂ | 1 |
| C | 26 | 8 | 43 | ..... | 1 |
| C | 26 | Aug. 5 | 71 | ♂ | 1 |
| E | 27 | July 11 | 45 | ..... | 1 |
| 1777 | 30 | 31 | 62 | ♀ | 1 |
| 15268 | June 3 | 26 | 53 | ♂ | 1 |
| 15284 | 6 | 26 | 50 | ♂ | 1 |
| H | 9 | 31 | 52 | ♂ | 1 |
| H | 9 | Aug. 12 | 64 | ♂ | 1 |
| G | 12 | July 31 | 49 | ♂ | 1 |
| 1792 | 12 | Aug. 2 | 51 | ♀ | 1 |
| I | 16 | 12 | 57 | ♀ | 1 |
| J | July 21 | Sept. 3 | 44 | ..... | 2 |
| J | 21 | 4 | 45 | ..... | 8 |
| J | 21 | 5 | 46 | ..... | 5 |
| J | 21 | 7 | 48 | 6 ♂<br>6 ♀ | 12 |
| J | 21 | 8 | 49 | 1 ♂<br>1 ♀ | 2 |
| J | 21 | 9 | 50 | 1 ♂<br>2 ♀ | 3 |
| J | 21 | 14 | 55 | ♂ | 1 |

[1] The records designated by letters were made in 1914; in other cases the first two figures of the cage number indicate the year in which the records were made.

TABLE I.—*Rearing records of Crambus mutabilis under observation in the laboratory or insectary from egg to adult*—Continued

| Cage No. | Eggs laid. | Moth out. | Number of days. | Sex. | Number of moths. |
|---|---|---|---|---|---|
| J | July 21 | Sept. 23 | 64 | ♂ | 1 |
| 15406 | 24 | 11 | 49 | ♂ | 1 |
| 15406 | 24 | 13 | 51 | 5 ♂<br>4 ♀ | 9 |
| 15406 | 24 | 14 | 52 | 1 ♂<br>3 ♀ | 4 |
| 15406 | 24 | 17 | 55 | 1 ♂<br>1 ♀ | 2 |
| 15414 | 27 | 18 | 53 | ♀ | 2 |
| 16221 | 29 | 22 | 55 | ♂ | 1 |
| 16221 | 29 | 24 | 57 | ♂ | 1 |
| 16221 | 29 | 29 | 62 | ♂ | 1 |
| 16221 | 29 | Oct. 1 | 64 | ♀ | 1 |
| 16221 | 29 | 3 | 66 | ♂ | 1 |
| 16221 | 29 | 17 | 80 | ♂ | 1 |
| 16221 | 29 | 19 | 82 | ♀ | 1 |
| 16221 | 29 | Nov. 6 | 98 | ♀ | 1 |
| 16221 | 29 | 14 | 102 | ♀ | 1 |
| 16221 | 29 | Apr. 23 | 268 | ♀ | 1 |
| 16221 | 29 | May 21 | 296 | ..... | 1 |
| 15476 | Aug. 6 | Oct. 19 | 74 | ♀ | 1 |
| 16260 | 11 | Apr. 23 | 255 | ..... | 2 |
| 16259 | 16 | May 2 | 259 | ..... | 1 |
| 16259 | 16 | 21 | 278 | ..... | 1 |
| 16259 | 16 | 27 | 284 | ..... | 2 |
| R [2] | Sept. 11 | Dec. 9 | 58 | ♀ | 1 |
| 15607 | 12 | May 26 | 256 | ♂ | 1 |
| 15602 | 17 | June 2 | 258 | ♀ | 3 |
| 15619 | 27 | 1 | 247 | ♂ | 2 |
| 15619 | 27 | 5 | 251 | ♀ | 1 |

[2] Reared in laboratory

Table II is a record of all the rearings of larvæ collected in the field, showing in most cases the interval between the activity of the larvæ in the spring and the appearance of the moths of the first generation. The data apply to middle Tennessee unless otherwise stated.

TABLE II.—*Rearing records of Crambus mutabilis larvæ collected in the field*

| Cage No. | Larva taken. | Moth out. | Sex. | Source. |
|---|---|---|---|---|
| 182 | Apr. 3 | May 25 | ♂ | Grass roots; fed blue grass. |
| 15141 | 20 | 24 | ♂ | Blue grass. |
| 1655 | 21 | June 27 | ♀ | Grass. |
| 1824 | 29 | 3 | ♀ | Corn. |
| 12358 | May 9 | 13 | ♀ | Corn. |
| Field note | 10 | ..... | ..... | Clump grass; not reared. |
| 16104 | 10 | May 29 | ♂ | Grass. |
| 12358 | 15 | June 8 | ..... | Corn. |
| 15359 | July 7 | July 27 | ♀ | Blue grass. |
| 15359 | 7 | Aug. 9 | ♀ | Blue grass. |
| C999G | 27 | Sept. 10 | ..... | Timothy, Athens, Ind. |
| C1037 | Aug. 6 | 5 | ♂ | Timothy, Nortonville, Ky. |
| 15641 | Sept. 30 | ..... | ..... | Timothy, La Fayette, Ind.; not reared. |
| 15687 | Nov. 9 | ..... | ..... | Blue grass, Nashville, Tenn.; not reared. |

A series of 50 larvæ from eggs laid July 23 was reared for individual instar records. Each larva was confined in a half-ounce tin box floored with damp blotting paper and was fed blue grass. A record was made of each molt, and the results are condensed in Table III.

TABLE III.—*Instar records of 50 Crambus mutabilis larvæ from eggs laid July 23, 1915*

| Stage. | Maximum. | Minimum. | Average. | Number of individuals included in average. |
|---|---|---|---|---|
| | *Days.* | *Days.* | *Days.* | |
| Egg | 7 | 7 | 7 | ..... |
| Larva: | | | | |
| Instar I | 5 | 3 | 3.2 | 50 |
| II | 5 | 2 | 3.3 | 48 |
| III | 4 | 3 | 3.3 | 44 |
| IV | 5 | 3 | 3.3 | 41 |
| V | 7 | 3 | 4.1 | 36 |
| VI | 7 | 3 | 4.8 | 29 |
| VII | 17 | 9 | 14.1 | 19 |
| Pupa: | | | | |
| ♂ | 11 | 7 | 9.9 | 8 |
| ♀ | 10 | 7 | 8.0 | 8 |
| Total | 56 | 50 | 52.6 | 16 |

## THE MOTH

### HABITS

The moths of this species (fig. 2) are essentially grass lovers and are seldom found among weeds or bushes. They are reluctant to leave tall grass for a mown field or closely grazed pasture and when driven out will at once circle back. They alight abruptly, usually on a grass stem, and instantly turn head downward and stand with the head pressed closely to the stem and the body elevated at a considerable angle. When at rest the dark costal margin of the fore-wing contrasts with the paler gray median portion and with the pale gray underbody, giving the moth an almost striped appearance when viewed from the side. This coloring and the characteristic attitude make this species one of the easiest to identify at a distance in the field. The moths are most often found in abundance in the lower and damper portions of the meadow, seemingly attracted by the greater luxuriance of the grass. They also occur in open woodland, especially if the ground is grass-covered. Their flight is erratic and awkward.

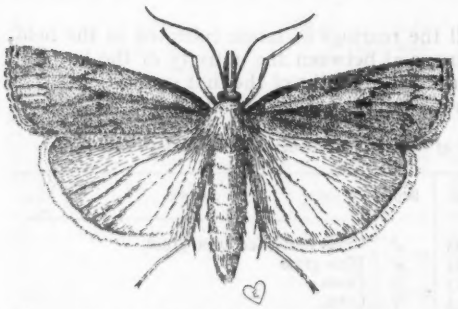

FIG. 2.—*Crambus mutabilis:* Adult female. About three times natural size.

All-night collections at light made throughout the summer in 1915 show that the female moths are attracted during the early part of the evening, between 8 and 9 o'clock and the males not until later, between midnight and 3 a. m. Very few of either sex appeared outside their respective periods.

It was proved by numerous experiments that the moths will feed on dilute honey and will drink water, but that food is not necessary and that they will live longer and the females will produce more eggs on the average when supplied with water alone than when fed honey or when confined in a dry box or vial. Moths in the field have never been observed feeding, or attracted to flowers.

The average length of life of 72 female moths taken at light and in the field and confined, some in dry boxes and some with wet cotton, was 3.86 days. Under the same conditions 115 males averaged 1 day less. One reared female, which had access to water from the time she emerged, lived 10 days and laid 500 eggs, which is probably about normal for a moth in the field. Under optimum conditions 3 males lived 14 days each, but a summary of all records shows that the males are usually shorter-lived than the females.

Practically all eggs obtained from moths taken in the open are fertile, indicating that mating occurs very shortly after the emergence of the females, probably the same night. Occasionally the last few eggs laid by a female prove to be infertile, but in most cases one mating is enough to fertilize the entire supply of eggs, and there is no evidence that the moths normally mate more than once. Female moths isolated and prevented from mating usually deposit some eggs, but these invariably shrivel and fail to hatch.

## DESCRIPTION (FIG. 2)

Wing expanse 18 to 24 millimeters, the females averaging larger than the males. General color gray, with a dusky spot near center of forewing, the inner half of costal margin dark brown. Palpi fuscous, the tips of the scales whitish. Head and thorax gray-brown. Male antennæ broadly pectinate (Pl. 2, A), female setaceous. Forewing with costal half slaty gray, sometimes whitish toward the center, anal half with a tinge of luteous. Proximal half of costal margin broadly bronze-brown. A dark brown median line begins near the middle of costal margin, forms a broad angle near end of cell, broadens immediately below it, and continues in an oblique line, gradually narrowing until it reaches the hind margin. In feebly marked specimens this median line is often obsolete except the portion below the end of the cell, which is invariably present as a more or less conspicuous dusky spot. Subterminal line runs nearly straight across the wing, with an acute outward angle at each vein. Terminal line of seven dusky spots at the ends of the veins. Fringes gray, shining. Hind wings gray, a little paler toward base, fringes pale yellow.

GENITALIA.—Male: Body of tegumen (Pl. 2, C) rather long, a little longer than the uncus, rounded above, its limbs long, narrow, turned ventrad, and narrowed at the ends. Uncus nearly straight, rather narrow, with a sharp, nail-like hook at the end, hirsute above. Gnathos long, slender, much exceeding the uncus, tip narrowed and turned slightly ventrad, naked. Aedoeagus (Pl. 2, E) straight, cylindrical, smoothly rounded cephalad, tapering somewhat from the opening to the tip, which flares slightly, terminal opening oblique, with a single long slender heavily chitinized cornutus, about half the length of the organ; anellus reduced to a mere membranous scale on ventral side. Harpes (Pl. 2, D) small, rather weakly chitinized; free costa reduced to a slender sharp spine less than half the length of the free sacculus, outer margin at base hirsute; sacculus with the free portion a flat curved process with rounded tip, hirsute, the hairs on ventral half much shorter than those above, narrowed at base, and with a rounded spined lobe where it joins the base. Vinculum reduced to a small scutate plate lying between the tips of the base of the sacculi. Female: The ventral two-thirds of the genital plate (Pl. 2, F) rounded and somewhat produced, the dorsal lobe smaller, rounded, both lobes hirsute.

## THE EGG

### DESCRIPTION

Elliptical in outline, bluntly rounded at the ends, one of which is very slightly more obtuse than the other. Length, 0.494 to 0.441 millimeter, average, 0.479 millimeter; width, 0.318 to 0.265 millimeter (average, 0.306 millimeter). The chorion is ornamented with prominent acute longitudinal ridges, usually 17 in number but varying from 16 to 20. These ribs become obsolete at the ends of the egg, where the polar disks are only slightly tuberculate; in the intervals between the ribs are much smaller cross striæ, about 30 in the length of the egg (Pl. 1, C).

The eggs laid by one female are very constant in size and shape, but there is enough variation between those from different moths to make the measurements of little value for specific determination.

The eggs are very pale cream, almost white when laid, but they soon deepen in color, reaching a pale salmon yellow in about three days, after which, until maturity, the color remains unchanged. After the third day the minute dark eye spot is visible within the egg. A few hours before hatching the darkening of the head and thoracic plate gives a purplish tinge to the whole mass of eggs. The egg is cut slightly to one side of the larger end and the larva escapes through a more or less ragged opening, leaving the parchmentlike shell nearly transparent.

### NOTES

In summer the eggs hatch in from five to seven days, the variation evidently depending on the temperature. When fully developed the larva leaves the egg regardless of outside conditions and does not remain quiescent as do some others of this group. The eggs are perfectly dry and nonadhesive when laid, and fall down among the grass stems as they are dropped by the moths either in flight or at rest. Their small size and lack of definite location make them hard to discover; and to find one a prolonged search is necessary even when they are known to be abundant.

Dissection of two freshly emerged moths showed, respectively, 560 and 1,120 eggs and egg cells in the ovaries. In the latter case the abdomen also contained a large amount of fat in the form of small bodies about the size of the matured eggs, but whiter and more irregular in shape. The first moth showed a much smaller quantity of this reserve supply, which is probably accounted for by less favorable feeding conditions during the latter part of the larval life. This partial starvation of the larva seems to affect directly and very decidedly the fecundity of the moths.

So far as the writer has been able to determine from many experiments with this and other species of Crambus, the females do not require food other than water for the development of the immature ova in the ovaries at emergence. Spent moths show an entire absence of fat bodies and immature ova, the youngest of these having evidently broken down and been used for the nutrition of the larger eggs. So while there were 1,120 eggs and egg cells in the more fecund of the two moths mentioned above, the actual number of eggs which she would have matured would have been much less than that, perhaps 700, and not over 350 for the other. The largest number of eggs produced by a single moth of this species, of which the writer has record, is 753 eggs, and very few attained 500. The average number produced by moths taken in the field and at light was 170, but many of these had doubtless laid part or all of their supply before capture.

## THE LARVA

### HABITS

The larva of *mutabilis* is one of the easiest to recognize in the field. The distinct striping of the body and the prominent dark markings of the head distinguish it. When newly hatched the head and cervical plate are shining jet black[3] and the body pale grayish yellow except for the spot of color in the intestinal tract, due to the bit of eggshell eaten in leaving the egg. The pinacula are dusky and unusually conspicuous for the first instar. During the first three instars the head remains black or very deep fuscous. In the fourth and succeeding instars it becomes brownish yellow, marked in a definite pattern with close groups of small, round, dark brown or black spots.

In the writer's experiments many larvæ were reared on blue grass, small sods of which were potted and covered with lantern globes. The newly hatched larvæ begin to feed by cutting small pits between the vascular bundles on the upper surface of the leaf blade, usually toward the base. These pits are soon covered with a few silk fibers, and shortly the larva is concealed by excrement placed systematically in this webbing. During the first three instars, only the green leaf tissue is consumed, leaving the lower epidermis intact; thereafter the entire thickness of the leaf is eaten. As soon as the larva becomes too large to remain sheltered on the leaf blade it descends to the ground and makes a burrow lined with silk and opening usually close beside the stem. In the field there is often a valve-like arrangement at the tip of this tube, so that the larva from within can close it and remain secure from intrusion. Beneath the surface the burrow may run at almost any angle. If the earth is soft it frequently is parallel with and close beside the main stem of the plant; if the ground is hard, it may run off at right angles just beneath the surface. The upper part of the tube is rather substantially constructed and closely lined with silk. Farther down the silk is more sparingly used and often just above the lower end ceases altogether, leaving only the earthen walls. The extreme lower end is again lightly lined with silk. This peculiar construction serves a very useful purpose in protecting the larva. When the plant is disturbed the larva instantly retreats to this silk-lined extremity of its burrow. If the plant and burrow be dug or pulled from the ground the tube breaks at its weakest point. The larva draws the earth-covered silk lining tightly about itself and so closely resembles a mere lump of earth that surprisingly often it escapes further detection. These larvæ become very large and brightly colored and but for the protection of this bit of webbing would be the most easily discoverable of the webworms.

Although in the cornfield the burrow often runs into the ground close by the stem of the plant, very little if any feeding is done beneath the surface. Quite unlike *caliginosellus*, which occupies a half-cylindrical tube lying against the stem and feeds exclusively underground, *mutabilis* always has an exit to the outside and feeds aboveground. The leaves are eaten, beginning at the base, and as they are cut fall away from the plant and lie wilting on the ground. Sometimes so many leaves are cut in this way that to obtain green food the larva is forced to consume

[3] Felt's (*4*, *p.* 65) surmise as to variations in the color of the head of the newly hatched larva is clearly an error, for the head colors of the first instar of the various species are remarkably constant.

the main stem of the plant, working from the top downward. In such cases the injury closely resembles cutworm work. Only the first-generation larvæ work on corn, and then usually only when it is very small.

In sod the injury is not so characteristic. The larva merely lives in its silk-lined tube, cuts off one blade of grass at a time, and draws it down into the burrow, where it is consumed at leisure. It is doubtful if the larvæ leave their burrows in the daytime, but they will feed during the day, as can be seen by the motion and gradual disappearance of a grass blade inserted into the burrow. All excrement is packed into the lower end of the burrow or sometimes into side pockets forking from the main burrow. When one burrow becomes too small, or is filled with the bright green sawdustlike frass, it is abandoned and another constructed. Occasionally a burrow is found as a silken tube running back under a board or stone lying on the surface of the ground.

Felt (*5, p. 69–74*) and other writers have described and figured definite cylindrical nests made by crambid larvæ, but these have been observed by the present writer in only one instance, and that in connection with this species. In this case numbers of larvæ were confined in lantern-globe cages with small potted sods of blue grass. They had reached about the fifth instar in late September, and at once constructed tubular nests of bits of dry grass blades tightly fastened together and smoothly lined with silk. They were suspended among the leaves of the blue-grass plants, some of them partly in the ground and some entirely above and clear of the ground. (Pl. 1, A.) They contained no excrement and were closed at the bottom, but open at the top. The larvæ seemed to make no effort to close them and wintered successfully in them, although exposed to every change of temperature in an open outdoor insectary. After the construction of these nests the larvæ fed no more until the following spring. It seems probable that such nests are constructed only when the soil is excessively wet, in order that the larva may remain dry during the cold weather. Excessive moisture and dryness are both enemies of larvæ overwintering in cages, and it is difficult to provide exactly proper conditions for them. From these and other observations it may be concluded that in Tennessee the larvæ construct and enter their winter quarters about the last of September. They begin feeding again in April, and the first moths make their appearance about the middle of May.

Two series of 10 larvæ each were run at different times to obtain records of the amount of food eaten. Blue-grass leaves cut into 30-millimeter lengths were used for food. At the close of each instar the uneaten portion was removed and measured. Since the larvæ skeletonize the leaves during the first three instars of their life and the total amount consumed during that time is insignificant, these instars are omitted from the record. The figures represent linear millimeters of blue-grass leaves of an average width of about 3 millimeters. The results of the two series were so similar that they are combined in Table IV.

As indicated by this somewhat incomplete record, the voracity of the larvæ of this species is low compared with that of *Crambus trisectus*, in which the average total consumption amounted to over 2,000 millimeters. This may be another reason why this species has not caused as serious injury as some of the others.

TABLE IV.—*Record of food eaten by larvæ of Crambus mutabilis*

[Linear millimeters of blue-grass leaves, average width about 3 millimeters.]

| Instar. | Maximum. | Minimum. | Average. | Number of larvæ. |
|---|---|---|---|---|
| | *Mm.* | *Mm.* | *Mm.* | |
| IV | 60 | 5 | 33 | 20 |
| V | 135 | 50 | 93 | 20 |
| VI | 480 | 35 | 183 | 19 |
| VII | 1,140 | 90 | 496 | 18 |
| VIII | 576 | 68 | 268 | 4 |
| Total | ..... | ..... | 1,073 | ..... |

The normal number of instars for *mutabilis* appears to be seven. Two larvæ pupated from Instar VI, but neither lived until emergence. The males and females develop in very nearly the same time, showing a difference of only 0.2 of a day between the averages for 8 of each sex.

The width of head and average length of the larva in each instar are shown in Table V.

TABLE V.—*Larval measurements of Crambus mutabilis*

| Instar. | Number measured. | Head width. | | | Body length. |
|---|---|---|---|---|---|
| | | Maximum. | Minimum. | Average. | |
| | | *Mm.* | *Mm.* | *Mm.* | *Mm.* |
| I | 8 | 0.194 | 0.194 | 0.194 | 1.77 |
| II | 6 | .301 | .301 | .301 | 2.80 |
| III | 4 | .459 | .424 | .441 | 3.08 |
| IV | 5 | .582 | .547 | .570 | 5.00 |
| V | 5 | .900 | .812 | .847 | 9.00 |
| VI | 11 | 1.306 | 1.166 | 1.227 | 13.00 |
| VII | 3 | 1.912 | 1.586 | 1.730 | 18.00 |

## DESCRIPTION

INSTAR I.—Head shining black, cervical plate fuscous, prothorax a little darker than abdomen, mesothorax and metathorax concolorous with it. Abdomen pale transparent yellow. Pinacula on thorax and abdomen dusky and conspicuous, unusually so for the first instar in this genus.

INSTAR II.—Head shining black, frons deep fuscous, cervical plate castaneous, a little paler and more reddish than head. Rest of thorax and abdomen pale yellow. Pinacula dusky and conspicuous, for each is surrounded by a small area of brownish overcolor.

INSTAR III.—Head shining black, frons paler, fuscous; cervical plate fuscous, rest of thorax and body pale, tinted by the ingested food, skin finely granular. Pinacula brownish, rugose, more or less conspicuously surrounded by a brownish area. Caudal plate pale with dusky dots.

INSTAR IV.—[No description obtained.]

INSTAR V.—Head dark yellow with clearly defined yellowish brown markings made up of round spots arranged in broken groups but in a definite pattern as follows: One area bordering the vertical suture and extending down on to the face in a branch each side of the frons; another larger triangular area with its base on caudal margin of head, extending forward until its tip joins the forks of the vertical spot; below this a smaller crescent-shaped area midway between the frons and caudal margin of

head; and below this a line running from the ocellar area to the caudal margin of the head. This pattern remains constant throughout the remaining instars. Cervical plate dusky yellow with small dark spots. Body color pale greenish yellow tinged with a faint claret or maroon overcolor. There are four longitudinal rows of whitish spots, one on each side of the narrow middorsal line and a broader one on each latero-dorsal aspect above the spiracles, giving the larva a striped or spotted appearance. Venter pale green, skin finely granular and glistening. Pinacula dark yellowish brown, rugose.

INSTAR VI.—Head dusky yellow with conspicuous groups of round fuscous spots; frons concolorous with head. Cervical plate yellowish brown, with several dark spots. Rest of thorax and abdomen entirely covered with the brown overcolor except for the four longitudinal pale or greenish lines which are more conspicuous in this instar. Pinacula darker than body, nearly concolorous with dark markings on head. Black cicatrices on the pedal segments of the abdomen about the size and shape of the spiracles. Caudal plate dusky yellow with dark markings.

INSTAR VII.—Head as in Instar VI with the markings more sharply defined. Cervical plate dusky yellow with a faint, dark-bordered pale median line, otherwise as in Instar VIII.

INSTAR VIII.—Head dusky or amber yellow, with dark markings composed of close groups of round yellowish brown spots arranged as described under Instar V. Frons dusky yellow, outlined with a very fine dark line and outside a pale V, which at apex continues caudad to the vertical suture. Cervical plate dusky yellow, with narrow, dark-bordered pale median line and some small dark markings. The four rows of irregular whitish spots give the larva a distinctly striped appearance. Pinacula yellowish brown, leathery, shining, rugose. Cicatrices larger than spiracles, black. (Pl. 2, B.)

## THE PUPA

### DESCRIPTION

The pupa is pale yellow when first formed, soon changed to a golden yellow, the head, thorax, and wing cases darkening as it approaches maturity. Spiracles are present on abdominal segments 3 to 9, inclusive, those on segment 3 almost under the edge of the wing cases, those on segments 5 to 8 elevated, the one on segment 9 pale and merely a scar. Anal process rather narrow (Pl. 2, G), a dorsal rounded ridge of nearly uniform width running to the rather truncate and downwardly bent tip. At the angles of this tip stand the setæ of the dorsal pair, very small, depressed, and inclined cephalad. At each side of the dorsal ridge is a flattened depressed area cut by the deep, wide, curved nasal groove at whose caudal end stands a small tubercle. Ventrad this anal process is more tapering and ends in a rounded elevation from the side of which arises the ventral pair of setæ, somewhat larger than the dorsal pair and diverging. Cephalad of this terminal elevation are four or five shallow, parallel, longitudinal depressions as if made by fingers laid side by side. The tip of the abdomen beneath is flattened but not concave.

### THE COCOON

When fully grown the larva makes its cocoon (Pl. 1, B) either by walling off a section of its burrow or constructing a separate chamber near by in the soil, more often the latter. The cocoon is about 15 millimeters long and half as wide, shaped like a peanut meat, rather firm to the touch, lined with soft gray silk and outwardly covered with earth particles so that it is not easily found. It lies close to the surface of the ground and when buried deeper has an extension reaching the surface. In emerging the moth leaves the pupal shell entirely within the cocoon.

## SYSTEMATIC RELATIONSHIPS

*Crambus mutabilis* appears to be the ultimate of one series in this genus. It differs from *hemiochrellus* (*1*, *p. 57*), its nearest relative, in the greater development of the antennæ and the reduction in the male genitalia. The male antennæ are more strongly pectinate than those of *hemiochrellus;* in fact, more so than in any other species of the genus which the

writer has seen. Each of the median segments bears from 14 to 18 sensoria (Pl. 2, A) compared with 8 or 10 in *hemiochrellus*. The male genitalia give the best basis for comparison. The free costa, which in *hemiochrellus* is a stout naked spine as long or longer than the sacculus, is in *mutabilis* a small slender spine less than half the length of the sacculus, which remains practically the same. The tegumen and uncus retain much the same shape, but the cornutus (Pl. 2, E) in the aedoeagus is both shorter and more slender than in *hemiochrellus*. The wing shape and the general uniform coloration remain similar in the two species, and the eggs of the two assume and retain exactly the same color during the incubation period.

## NATURAL CONTROL

That this species has not more frequently been recorded as a destructive pest is probably due to two factors—the apparent great susceptibility of the larvæ to disease, and the attacks of parasites.

### DISEASES

While making intensive studies of this species at Nashville, Tenn., in rich blue-grass meadows, where the larvæ were known to be abundant, areas were often found in which practically every burrow contained only the flaccid dead body of the maker. The same disease, evidently bacterial, was met with in the laboratory, and it was only by using the strictest care in the sterilization of the tin boxes used as rearing cages that it was possible to bring the larvæ to maturity. The disease first manifests itself in the lack of appetite and sluggishness of the larva. The next day the larva is dead and somewhat softened, but not externally changed. Another day reduces it to a shapeless sack filled with a dark brown semiliquid. Finally the skin also breaks down and the mass gradually dries up, leaving only a dark stain. The writer has not succeeded in getting a determination of the cause of the disease, but that it plays a very large part in keeping this species from becoming a serious pest can not be doubted.

Another disease which is less common kills the larva more gradually. It usually begins at the caudal end and leaves it corky in texture and densely filled with a mass of whitish hyphæ. The fungus causing it has been determined by Dr. A. T. Speare as a species of Isaria.

### PARASITES

Because of the fact that the larvæ of this species have a more open method of feeding than some of the others, they appear to be more subject to the attacks of parasites than those which remain more constantly underground.

Two species of tachinid flies have been reared from larvæ of *Crambus mutabilis*, namely *Phorocera claripennis* Macq. and *Exorista nigripalpis* Towns., neither of which apparently has heretofore been recorded from this host. Both were reared from larvæ collected by W. H. Larrimer in connection with an outbreak of webworms near La Fayette, Ind., in June, 1920, in which two species of Crambus were concerned, *C. trisectus* and *C. mutabilis*, the former predominating to the extent of about 80 per cent of the total.

Fifteen flies of the species *Phorocera claripennis* Macq. were reared from 14 host larvæ, two of them maturing, in one instance, from one host.

One came from a larva determined before its death as *Crambus mutabilis* and the others all from mixed larvæ specifically undetermined. It is therefore unknown whether this parasite is limited to the single host or divides its attentions between the two. Further rearings are necessary to settle this point. The mature maggots of this species almost invariably issued from their host while it was still a larva and from one to three days after its death, leaving only an empty head shell and a shriveled skin. The adult flies appeared from 11 to 19 (average 13.5) days after pupation. The eggs are white and conspicuous and are attached to any part of the host, most frequently about the thoracic segments. As many as 14 eggs have been seen on one individual, but it seems very unusual for more than one of the parasites to reach maturity, at least on a host of this size. In the one such case observed both of the two flies appearing were very small and one failed properly to expand. In fact, this fly does not seem to have the vigor of *Exorista nigripalpis*, for, although reared under exactly similar conditions, nearly half of them failed properly to expand their wings upon emergence, and some failed even to free themselves from their puparia. Several of the crambid larvæ which yielded these flies did not have eggs on them when collected, but the shells had probably been molted off after maggots had hatched and entered their host.

Only a single fly of the species *Exorista nigripalpis* Towns. was reared from a larva previously determined as *mutabilis*, and as a considerable number were obtained from larvæ known to be *trisectus* this parasite is discussed in a forthcoming paper dealing with *trisectus*.

The writer has records of two species of hymenopterous parasites attacking *Crambus mutabilis*.

*Apanteles crambi* Weed has been recorded from other species of the genus, and recently (*10, p. 546*) from *mutabilis* from South Dakota and Tennessee. When full-grown the grubs of this parasite emerge from their host and spin a mass of white cocoons near by. The host remains alive for several days, but finally dies without moving or feeding. The adult parasites emerge in six or seven days after the cocoon is formed.

*Macrocentrus crambivorus* Vier. has been reared twice from larvæ of *Crambus mutabilis* at Nashville, Tenn. In both cases the host larvæ were nearly full grown but appeared abnormally pale when collected. In the rearing box each constructed a silken case, and when this was examined a little later the larva had been replaced by a dense mass of elongate yellowish brown cocoons, 20 or 25 in number. The following day the white pupæ could be seen indistinctly through the cocoons. The parasites became adult and active within their cocoons eight or nine days later, but their actual emergence seemed to be entirely dependent on proper conditions of humidity. In one instance the adults, although active within the cocoons, did not emerge until the stopper of the vial was moistened, whereupon they all released themselves within five minutes. Other groups behaved in the same way unless they had been so long confined to their cocoons that they were unable to emerge at all. The adults are slender, yellowish brown in color, and very active. The females trail a long threadlike ovipositor behind them. In the writer's rearings all those emerging from a single mass of cocoons were of one sex. Others, also apparently of this species (determined by S. A. Rohwer as *Macrocentrus* sp.) were reared from two of the undetermined larvæ taken at La Fayette, Ind., in June, 1920. One yielded 14 males and the other 29 females.

## ARTIFICIAL CONTROL

Injury to corn by the striped sod webworm can more easily be prevented than remedied. When a field is in meadow or pasture, the moths are attracted to the low, rich portions where the grass growth is most luxuriant. If a sod field be broken and planted to corn, injury is most likely to occur in such portions. To prevent the injury the sod should be plowed as early as possible in the fall, in late July or August if possible. Land plowed after the middle of September generally shows little reduction in infestation compared with that plowed in the spring, because by September the majority of the larvæ have entered their winter quarters, where they are not seriously injured by plowing. If the sod is plowed early enough to deplete seriously the food supply of the fall generation and force the larvæ into winter quarters in an undernourished condition and incompletely protected, the method may prove somewhat beneficial.

Where lands permanently in grass, such as meadows, lawns, and parks, are heavily infested, premature drying and browning of the plants may be caused, becoming especially evident during periods of drought. Little can be done in such cases except to stimulate the growth of the grass by applying a quick-acting fertilizer, such as nitrate of soda. Fortunately, the portion of a meadow most attractive to this insect is the last to suffer from unfavorable moisture conditions and remedial treatment in such places will very seldom be required.

Although poisoned bran bait has been tested in a few instances, for the most part unsuccessfully, no opportunity has as yet presented itself to give this method a thorough trial. It may yet be found feasible for use in heavily infested grasslands.

## SUMMARY

*Crambus mutabilis* is a common species over the eastern half of the United States and as far west as Iowa, Utah, and Texas. Its food plants seem to be limited to the grass family.

It has been known to cause injury to young corn and to grasslands, but in such cases it is usually associated with some other species.

There are three generations a year in Tennessee, the third being the smallest, and gradually diminishing northward until there are only two at the northern limits of the species.

The moths are grass lovers and seek the lower and more luxuriant portions of pastures and meadows. They lay about 500 eggs, dropping them promiscuously as they fly.

The larvæ in the larger instars are distinctly striped and easily recognized. They construct tubular burrows in the earth opening at the surface and feed on near-by grasses, cutting off the leaves and dragging them into the burrows. In the fall they construct tubular nests among the grass stems, either above or partly in the ground, and pass the winter as partly grown larvæ, completing their growth in the spring.

*Crambus mutabilis* is more specialized than *C. hemiochrellus*, its nearest relative, and is evidently the terminus of one line of development in the genus.

The larvæ seem very susceptible to disease and are also frequently parasitized by both Hymenoptera and tachinids.

Control measures consist of early fall plowing of sod lands intended for corn the following year and rotation of pastures and meadows where the insect is destructive. Ordinarily natural agencies prevent its injurious increase.

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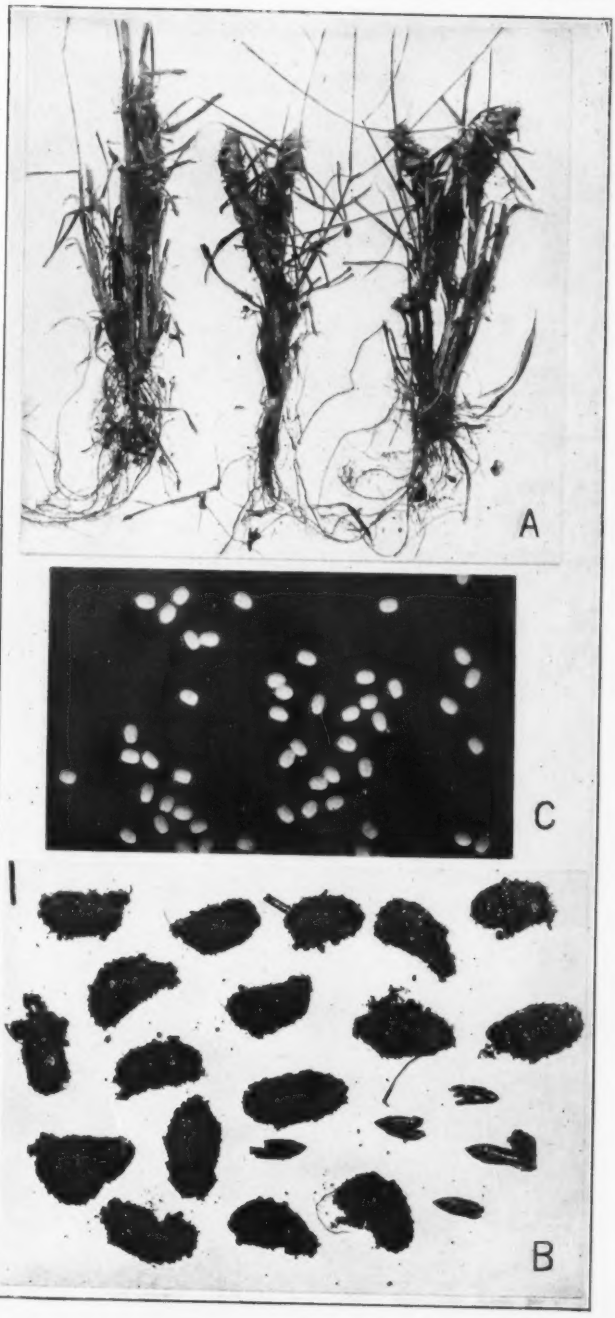
PLATE 1

*Crambus mutabilis:*

A.—Winter cases of larvæ on blue-grass plants.
B.—Pupal shells and cocoons.
C.—Eggs. Greatly enlarged.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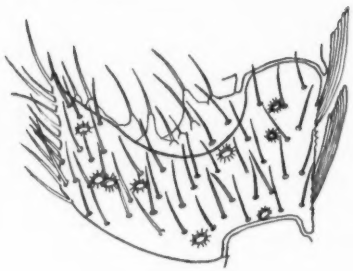

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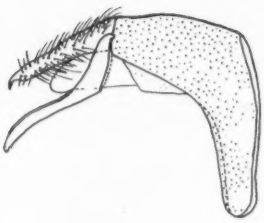

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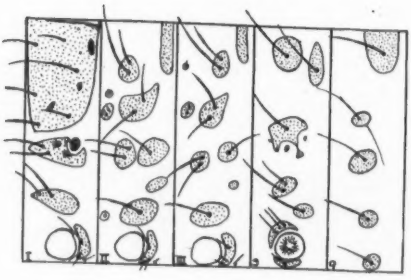

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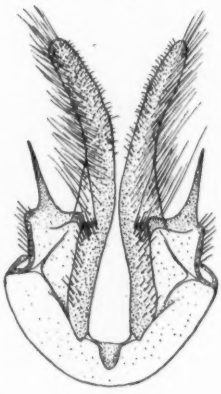

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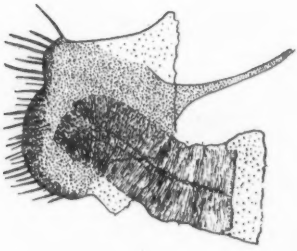

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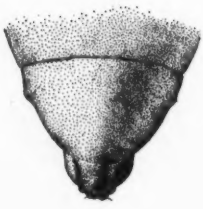

G

## PLATE 2

*Crambus mutabilis:*

A.—Male antennal segment (twenty-fifth), greatly enlarged.
B.—Setal map of three thoracic and third and ninth abdominal segments of larva.
C.—Male genitalia: Tegumen and uncus.
D.—Male genitalia: Harpes.
E.—Male genitalia: Aedoeagus.
F.—Female genitalia: Valve.
G.—Tip of pupa, dorsal view.

# SILVER-STRIPED WEBWORM, CRAMBUS PRAEFECTELLUS ZINCKEN[1]

By GEORGE G. AINSLIE

*Entomological Assistant, Cereal and Forage Insect Investigations, Bureau of Entomology, United States Department of Agriculture*

## INTRODUCTION

Although of less economic importance than many other members of the genus, *Crambus praefectellus* is so widely distributed that it is sure to be met with by anyone interested in these beautiful little moths. It is one of several species with a longitudinal silvery-white stripe in the forewing (fig. 2). It is most likely to be confused with *C. leachellus* Zincken, which, however, is a larger species with the white stripe running much closer to the costal margin of the wing than it does in *praefectellus*. *Crambus quinquareatus* Zeller and *C. unistriatellus* Packard also resemble it in size and general pattern, but in the former the apex of the wing is acuminate and in the latter the white stripe runs the full length of the wing, characters which easily distinguish their possessors from the species under consideration.

## SYSTEMATIC HISTORY

*Crambus praefectellus* was first described by Zincken (*9, p. 249*)[2] in 1821 from specimens sent him from Georgia. He placed it in the genus Chilo, which at that time was synonymous with what we now know as the subfamily Crambinae. Clemens (*3, p. 203*) redescribed it in 1860 as *Crambus involutellus*. In his revision of the group in 1863, Zeller (*8, p. 18*) placed Zincken's species in its present genus and incorrectly placed *involutellus* as a synonym of *leachellus* Zincken. In this he was followed, with some hesitation, by Grote (*7, p. 77*), but Fernald (*5, p. 45*) corrected the error and first placed *involutellus* Clemens as a synonym of *praefectellus* Zincken, a course approved by all later writers. The synonymy then stands as follows:

*Chilo praefectellus* Zincken, 1821
*Crambus involutellus* Clemens, 1860
*Crambus praefectellus* (Zincken) Zeller, 1863

Although the bibliography of this species comprises some 25 titles, the great majority of these are merely references to the occurrence of the moths in various localities. Felt (*4, p. 85*) figures and discusses the species, but since he did not find it at Ithaca, N. Y., where his work was done, he gives us no biological information. Fernald (*6, p. 31*) figures and describes the adult and concludes with the comprehensive statement, "Early stages and food plant unknown." Since that time Britton's paper (*2, p. 222*) is the only publication that adds to our knowledge.

[1] Accepted for publication July 11, 1922. This paper is the fourth in a series of Contributions to a Knowledge of the Crambinae of North America. I, *Crambus hemiochrellus* Zeller, appeared in Annals of the Entomological Society of America for March, 1918, and II, *Crambus laqueatellus* Clemens, appeared in the June, 1922, issue of the same journal. The third paper, entitled, "Striped Sod Webworm, *Crambus mutabilis* Clemens," precedes this paper in the Journal of Agricultural Research.

[2] Reference is made by number (italic) to "Literature cited," p. 424-425.

## GEOGRAPHICAL DISTRIBUTION

*Crambus praefectellus* is a strictly American species and seems to be limited to the eastern half of the United States. It has been taken in practically every State east of the Mississippi River and also in North Dakota, South Dakota, Minnesota, Iowa, Colorado, Missouri, Arkansas, and eastern Texas. It is reported from Cartwright, Manitoba, and also occurs in eastern Canada, at least along the southern edge. The accompanying map (Fig. 1) shows at a glance its present known distribution. The following list gives the States from which records are available and also gives the first and last date and the intervening months when collections have been made:

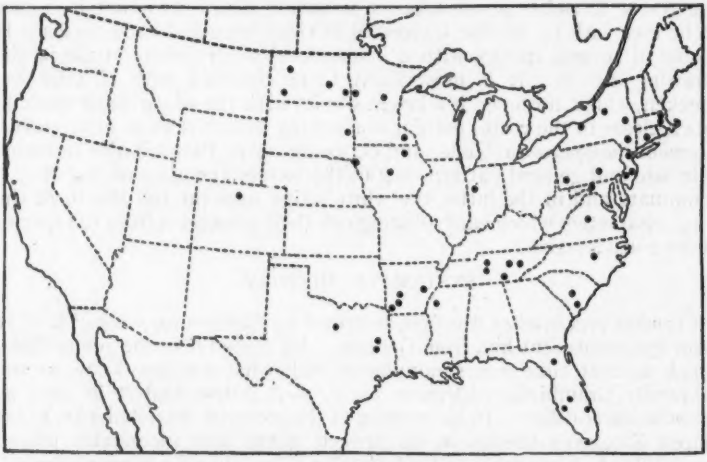

Fig. 1.—Map of the United States showing known distribution of *Crambus praefectellus*.

Arkansas. March 28, June, July 3.
Colorado. (Date uncertain.)
Connecticut. May 26, September 1.
Florida. February 7, March, April 30.
Georgia. (Date uncertain.)
Illinois. May 31, June, July, August, September 3.
Indiana. August 11, 12.
Iowa. July 8, August, September 6.
Kentucky. August.
Maryland. August 30.
Massachusetts. May 31, June, August 22.
Minnesota. June 19, July —.
Mississippi. May 3, June 22.
New Hampshire. August 1 to 7.
New Jersey. May —, June, July, August, September 11.
New York. May 21, June, July, August 18.
North Carolina. June —, July, August 23.
North Dakota. June 12, July 21.
Pennsylvania. May 24, June, July, August 19.
South Carolina. April 1 to 7.
South Dakota. June 24.
Tennessee. April 3, May, June, July, August, September, October 20.
Texas. January 30, March, April, May 22.
Virginia. September 5, 6.
West Virginia. May 30.
Wisconsin. September 10.
Manitoba, Canada. (Date uncertain.)
Ontario, Canada. June 4, July 6.

## FOOD PLANTS

Corn, wheat, rye, oats, blue grass (*Poa pratensis*), pigeon grass (*Setaria glauca*), and timothy (*Phleum pratense*) were all used as food plants in the writer's rearing cages and all were accepted readily by the larvæ.

Doubtless this list could be almost indefinitely extended. Judging from the habit of the moths in frequenting weedy waste ground in preference to grassy places, it is very likely that the larvæ also feed on plants other than grasses. The foregoing plants include all on which larvæ have been taken in the field.

## ECONOMIC HISTORY

While it can not be regarded as a serious pest, *Crambus praefectellus* in one or two instances has shown that it can cause considerable injury under certain conditions. Single larvæ have been taken destroying wheat at La Fayette, Ind., and corn at Lakeland, Fla., Prescott, Brinkley, and Hot Springs, Ark., and Knoxville and Caney Spring, Tenn. Larvæ were received from Advance, Mo., with the report that they had injured 50 acres of a 300-acre cornfield. Britton's (*2*) recent account is the only published record of injury by these larvæ. In this case a small field of corn in the outskirts of New Haven, Conn., was almost totally ruined. The field had been in grass previously, and was plowed in the spring and planted to corn. The plants were attacked while small, and so numerous were the larvæ that only a very few plants escaped injury and produced grain.

Just what factors in the life economy of this species prevent it from more often becoming destructive can not be stated. Probably parasites, predacious enemies, and disease all play their parts, but nothing is known about these. It is apparent that this insect has not in any special way adapted its life cycle to extremes of climate. It has no definite protective resting period and consequently is overtaken by winter and unfavorable weather in all its different stages, some of them unfitted to resist such conditions. The mortality from such causes must be very great.

If control measures were needed, probably the best would be early fall plowing of land intended for corn the following season. If this were done, and the planting delayed as long as possible in the spring, the ground meanwhile being fallow and free from weeds and grass, there should be very slight possibility of the larvæ surviving until the corn germinated. If the infestation is not discovered until the corn is up, as is usually the case, little can be done but to replant alternately with the old rows, allowing them to stand as long as possible before cultivating them out. This method is described more fully in another paper (*1, p. 15*).

## SEASONAL HISTORY

The earliest seasonal record for a moth of *Crambus praefectellus* is January 30, at New Caney, Tex. It has been taken at several points in Florida during February. In Tennessee, where continuous observations have been made for several years, the first moths make their appearance during April, usually toward the end of the month. It is always the first species of the genus to appear. On one occasion a battered male moth was taken at Knoxville on April 3. This is more than two weeks earlier than the moths have been taken in other years, and the pupa from which it emerged may have been formed in a particularly sheltered location.

After their first appearance the moths do not become abundant but are found singly and scatteringly throughout the greater part of the

summer. The generations are not distinct, although at some times the moths appear to average fresher than at others. It is very evident that they breed continuously and that the larvæ do not have any considerable resting period after completing their growth but pupate at once. Judging from laboratory rearing records, there are probably three generations during the year in Tennessee. Farther north this number may be lessened and at the southern limit of its range there are probably more. With a species such as this, in which the generations follow one another without intermission other than the delays due to unfavorable weather conditions, the number of generations in any given season is directly dependent on the length of the growing season and may vary from year to year.

All the available data as to the seasonal appearance of moths in other regions are so scattered and fragmentary that it seems impossible to draw any definite conclusions from them. In the list given under "Geographical distribution," the seasonal records are arranged by States. In the following list the same data are arranged by months, in order to show very incompletely the seasonal trend of the occurrence of the moths.

January..... Texas.
February..... Florida.
March..... Texas, Florida, Arkansas.
April..... Texas, Florida, South Carolina, Tennessee.
May..... Texas, Mississippi, Tennessee, West Virginia, Illinois, New Jersey, Pennsylvania, New York, Massachusetts, Connecticut.
June..... Mississippi, Arkansas, Tennessee, North Carolina, New Jersey, Illinois, Pennsylvania, New York, Massachusetts, Minnesota, South Dakota, North Dakota, Ontario.
July..... Arkansas, Tennessee, North Carolina, Illinois, Pennsylvania, New Jersey, New York, Iowa, Minnesota, North Dakota, Ontario.
August..... Tennessee, North Carolina, Kentucky, Illinois, Maryland, New Jersey, Pennsylvania, New York, New Hampshire, Massachusetts, Indiana, Iowa.
September.... Tennessee, Illinois, Virginia, Connecticut, New Jersey, Iowa, Wisconsin.
October..... Tennessee.

## THE MOTH

The writer has never found the moths of this species really abundant. Usually they have been taken very sparingly, one or two at a time and very seldom as many as half a dozen in a day's collecting. They were seen most abundantly at Greenwood, Miss., on the night of June 22, 1915, when 34 were taken at electric street lights between 8 and 11 p. m. In the field the moths seem to prefer more or less open, weedy or waste ground, such as neglected strawberry beds or fallow fields, rather than grassy places.

When the moths are flushed during the day, they usually fly only a short distance and may be readily captured with a small vial, but toward dusk they are much more wary, and when disturbed frequently fly 50 feet or more before settling. They alight, apparently without preference, on any part of an object, leaf, grass stem, or very frequently on the bare ground. They seldom rearrange their position after alighting. In the field, the silvery stripe and the brassy shade of the forewing in fresh specimens make them easy to identify at a considerable distance. Around lights at night they can be distinguished from *Crambus teterrellus* Zincken, the only other species of equal size with which they are apt to be asso-

ciated, by their habit of lying closely parallel with the surface on which they are at rest, quite in contrast with the moths of *teterrellus*, which rest with their heads pressed closely to the surface and their bodies elevated at an angle of 25°.

The data on hand show that these moths are not especially prolific, at least compared with some of the other species of this genus. The average number of eggs laid by the 41 females of which the writer has records was 118. This includes moths taken in the field and confined in dry vials and in tin boxes with water and with honey. The largest number laid by a single individual was 533, and only 9 of the entire 41 laid more than 200 eggs. The moths evidently mate immediately after issuing from the pupa, for not one of those collected in the field, some of them very fresh, laid infertile eggs.

There is nothing to indicate that the adults of either sex ingest anything besides water. They do not seem in the least attracted to flowers or other possible food sources. One moth excitedly waved her antennæ when approached with a droplet of honey and when finally induced to taste it, rapidly sucked it up. An attempt was made to determine if food in the form of dilute honey had any effect on the length of life or the egg production. The following table summarizes the results and leads to the conclusion that food has no pronounced effect above that of plain water, on either longevity or fecundity, but that either water or honey appreciably prolongs the life and increases egg production above that of moths confined in dry vials. As the majority of these moths were taken in the field, the averages as given are rather below than above the normal.

TABLE I.—*Relation of feeding to longevity and fecundity of moths of Crambus praefectellus*

| | Male. | | Female. | | | |
|---|---|---|---|---|---|---|
| | Longevity. | Number averaged. | Longevity. | Number averaged. | Eggs produced. | Number averaged. |
| | *Days.* | | *Days.* | | | |
| Water | 9.07 | 15 | 8.9 | 8 | 138 | 8 |
| Dilute honey | 7.45 | 20 | 11.25 | 12 | 134 | 12 |
| Dry | 7.75 | 4 | 6.72 | 18 | 96 | 21 |

## DESCRIPTION OF MOTH (FIG. 2)

Wing expanse, 18–25 millimeters. Head, palpi, and abdomen cinereous, the abdomen lighter. Thorax and forewings golden fuscous, the latter with a silvery white stripe bordered with a fine darker line and tapering toward each end, from base to near subterminal line, a tooth near middle of lower side, and a silvery white dash above the tip and often fused with it; from this dash a dark shade with a light costal triangle above it, a light patch below it, and crossed by the plumbeous subterminal line, runs to the apex of the wing. Costal margin wider than in *leachellus*, being more than one-half the width of the white stripe at the middle of the costa. Subterminal space with 5 blackish venular dashes. Fringes white or slightly tinged with ochreous. Hind wings white or slightly cream-colored, fringes white. (Rewritten from Fernald.) The male antennæ are plainly flattened, each segment bearing a wedge-shaped process, which, in the medium segments, is provided with 8 to 10 sensoria (Pl. 1, E). The female antennæ are filiform and are beautifully banded with narrow alternate rings of brown and white (Pl. 1, F).

GENITALIA.—Male: Tegumen (Pl. 1, D) with body very short, about one-third the length of the limbs, which are broad, nearly straight, and almost truncate at the tip. Uncus broad at base but quickly narrowing, slender, and of uniform width for the rest of its length, the distal third dorsad thickly set with short stout spines inclined cephalad, interspersed with a few sparse hairs; gnathos glabrous, its limbs widely separated at their tips but quickly narrowing to the slender body, which considerably exceeds the uncus. Harpes (Pl. 1, B) rather narrow at base, elongate and subfalcate in general shape; costa free except at base but much modified into a short chitinized process, incurved and truncate; cucullus lightly chitinized, strongly concave, widest just above the base and narrowing gradually to the rather obtusely rounded tip, very hairy within, with an especially thick tuft just above the base. Cucullus not sharply separated from the sacculus, which is subquadrate in general outline, with a thickened costal margin and on its disk near the ventral margin a stout, heavily chitinized finger-like spine. The vinculum is much reduced and is merely a band of lightly chitinized tissue connecting the bases of the harpes. Aedoeagus (Pl. 1, C) lightly chitinized, nearly cylindrical, rounded at the base and curved in the shape of an old-fashioned pistol; at the tip truncate and somewhat bell-shaped, the internal lining for half its length roughly tuberculate; just inside the tip is a very short, sharp, chitinized thorn-like cornutus, and about two-thirds toward the base another much larger, acute, oblique spine with a very long narrow base, its tip inclined toward the tip of the aedoeagus. Anellus a mere ventral membrane. Female: Anal plate (Pl. 1, G)

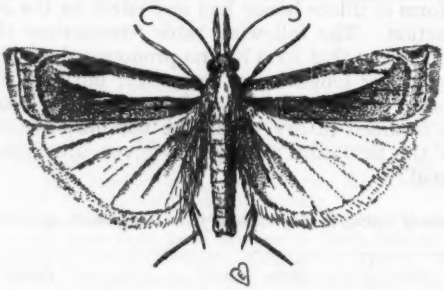

FIG. 2.—*Crambus praefectellus:* Adult. About three times natural size.

two-lobed, the dorsal lobe more feebly chitinized, about one-third the width of the lower, and separated from it by a deep notch, the margins of both lobes thickly set with stout setæ.

## THE EGG

As is the case with all other species of this genus so far as known, the eggs are dropped promiscuously by the female during the early evening as she flies about or stands at rest. They are dry and drop down among the grass stems to effectual concealment in the débris beneath.

The incubation period has varied in the writer's experience from 15 days in March in Florida to 5 days in June and July in Tennessee, with all intermediate gradations. During the growing season from 5 to 9 days seems to be about the usual duration.

Almost snow white when first laid, the egg day by day becomes first pink, then flesh color, salmon, and, finally, on about the fourth day, a bright clear coral-red. They remain thus until about 24 hours before hatching, when the head and cervical plate of the contained larva begin to darken, giving the eggs a purplish hue. The larva escapes through a somewhat irregularly cut hole at one side of the larger end of the egg, leaving the empty shell nearly transparent and slightly iridescent.

The eggs of this species are somewhat rounder and with the small end a little more acute than the average for the genus. With this as with

several other species, it is found that the variations among the eggs of different individuals, especially in size, were greater than those existing between this and other species, thus rendering interspecific measurements of very little value. In fact, it holds true throughout the genus that the eggs of the various species are so similar as to render them practically indistinguishable.

To indicate the variation in size of the eggs of this species, the following measurements of two lots of 10 eggs each were made at different times:

TABLE II.—*Egg measurements of Crambus praefectellus*

| Lot. | Length. | | | Width. | | |
|---|---|---|---|---|---|---|
| | Maximum. | Minimum. | Average. | Maximum. | Minimum. | Average. |
| | *Mm.* | *Mm.* | *Mm.* | *Mm.* | *Mm.* | *Mm.* |
| 1 | 0.5471 | 0.5118 | 0.5207 | 0.3353 | 0.3000 | 0.3106 |
| 2 | .5736 | .4633 | .5018 | .3442 | .2692 | .3149 |

The color is of interest because it has been found that the maximum color attained during the incubation period is very similar in the various subgeneric groups of closely related species, and differs between these groups from a pale straw-yellow to a deep coral-red. Thus the egg colors as well as the head colors of the newly hatched larvæ help to indicate the affinities of the various species.

The chorion is ornamented with acute longitudinal ribs, usually 21 in number, which become obsolete before reaching the poles. The polar areas are covered with scattered oval tubercles of variable size (Pl. 1, H). Between the ribs there are also less prominent cross carinæ, about 17 of these in the length of the egg. The egg is suboval in outline, one end slightly larger and more flattened than the other.

## THE LARVA

The writer has never taken larvæ in the field, and the only notes on their normal behavior are those contained in Britton's account (*2*) of the attack on corn in Connecticut. Even here the conditions were not strictly normal, for the grass sod in which the larvæ were living was plowed under in the spring and the field planted to corn, forcing the larvæ onto the young corn plants as the only available food. The larvæ fed in the manner usual to most of the species under similar conditions, cutting a hole into the tender stalk below the ground level and living in a fragile tube of silk and earth particles attached to the stalk and leading off into the ground. Except when actually at work the larva does not remain in the stalk, but in this tube, so that when the plant is pulled the author of the injury, together with most of its domicile, is likely to be left behind in the earth.

In the cages used the larvæ were reared without especial difficulty. For the most part 1-ounce or 2-ounce tin salve boxes floored with damp blotting paper were used and the food was supplied in the form of short sections of the leaves of various grasses, usually blue grass (*Poa pratensis*). Under these conditions the progress through the instars was easily watched. It was not always easy, however, to be sure that a

molt had occurred. The only sure proof was to find the cast of the head, but in this species the first act of the newly molted larva was in most cases to eat the head cast, often leaving nothing but the mandibles as evidence that ecdysis had really occurred.

The first food of the larva consists of the fragment of eggshell consumed in effecting escape from the egg. This particle becomes bright pink or salmon color in the intestinal tract. As soon as it is free from the egg the tiny caterpillar is ready for green food. When placed on a blue-grass leaf it begins operations by cutting a narrow pit lengthwise of the leaf, at first avoiding the veins. This pit soon becomes large enough to contain the entire body of its maker and then a few threads of silk are spun across above it. The excrement is placed on or among these strands and in a few hours the larva is practically concealed from sight by this filthy roof. After the first day or two the larva eats the small veins as well as the tissue between them down to the lower epidermis of the leaf, but not until it reaches the third instar does it consume the entire leaf blade. By this time it has become too large effectually to conceal itself on a blue-grass leaf, and thenceforth seeks the earth, where, for protection, it constructs a tubular retreat of mingled silk and earth particles. From this vantage ground it comes out, usually at night, to cut off and consume one by one the blue-grass leaves.

As stated above, the larvæ of this species do not spend any time in a resting period, but pupate as soon as fully fed, weather conditions permitting. Of course during the cool weather of spring and fall, and in the winter, their activities are much retarded or cease altogether, but as soon as warmer temperatures prevail feeding is resumed and the transformations completed.

The following tables give figures showing the maximum, minimum, and average periods required for the various instars and for the complete life history.

TABLE III.—*Length in days of various stages and instars of Crambus praefectellus*

A. EGGS HATCHING MAY 13

| | Eggs. | I. | II. | III. | IV. | V. | VI normal. | VI prepupal. | VII prepupal. | Pupa. |
|---|---|---|---|---|---|---|---|---|---|---|
| Maximum | 9 | 5 | 5 | 4 | 6 | 6 | 6 | 15 | 8 | 12 |
| Minimum | 9 | 3 | 2 | 2 | 3 | 4 | 4 | 7 | 8 | 9 |
| Average | 9 | 3.46 | 3.83 | 3.00 | 3.92 | 5.20 | 5.00 | 9.30 | 8.00 | 9.87 |
| Number of records averaged | | 26 | 29 | 27 | 27 | 25 | 2 | 19 | 1 | 15 |

B. EGGS HATCHING JUNE 25

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Maximum | 5 | 2 | 4 | 4 | 4 | 5 | 5 | 18 | 12 | 11 |
| Minimum | 5 | 2 | 3 | 3 | 3 | 2 | 5 | 11 | 12 | 10 |
| Average | 5 | 2 | 3.50 | 3.17 | 3.82 | 4.25 | 5.00 | 13.14 | 12 | 10.33 |
| Number of records averaged | | 14 | 12 | 12 | 11 | 8 | 1 | 7 | 1 | 6 |

TABLE III.—*Length in days of various stages and instars of Crambus praefectellus*—Con.

C. MISCELLANEOUS RECORDS. EGGS HATCHING APRIL 21 TO AUGUST 8

| | Eggs. | Larva. | Larva-pupa. | Pupa. | Entire developmental period. |
|---|---|---|---|---|---|
| Maximum | 15 | 38 | 85 | 18 | 71 |
| Minimum | 5 | 27 | 33 | 9 | 41 |
| Average | 7.73 | 31.5 | 51 | 11.3 | 51.5 |
| Number of records averaged | 22 lots. | 14 | 65 | 21 | ..... |

In addition to those included in the tables, the writer has records of a few individuals hatching on September 18, which emerged as adults between January 23 and February 26 of the following year, after having been kept in the cool room of the insectary all winter.

It will be noted that most of these larvæ pass through six instars before pupation, but occasionally there is a seventh instar. The last instar before pupation is always much longer than those preceding, so that in order to make the averages correct these records are separated as normal and prepupal.

Through an oversight, detailed color descriptions of the various larval instars except the first were not made. The molted head casts were preserved, however, and the following list of characters is drawn up from them:

TABLE IV.—*Head width of larvæ of Crambus praefectellus*

| Instar. | Minimum. | Maximum. | Average. | Number of heads measured. |
|---|---|---|---|---|
| | *Mm.* | *Mm.* | *Mm.* | *Mm.* |
| I | 0.229 | 0.229 | 0.229 | (a) |
| II | .335 | .300 | .325 | 8 |
| III | .529 | .459 | .512 | 7 |
| IV | .882 | .759 | .826 | 10 |
| V | 1.306 | .933 | 1.219 | 15 |
| VI | 1.493 | 1.306 | 1.399 | 2 |

[a] Large number measured, but exact number not known.

In the first instar the head is shining black, paling somewhat but still fuscous in II. In III the ground color is still paler, with faintly darker areas indicating the later color pattern. In IV these markings have become much darker and more distinct, and the ground color of the head has become pale yellow. In the next two instars the colors remain the same, but become more intense. The color of the body of the larva through most of its growing period is a dull brown with a greenish tinge from the contents. The arrangement of the pinacula and setæ is shown in Plate 1, A.

## THE PUPA

The cocoon is a little case about the size and shape of a peanut meat, lined and stiffened with gray silk inside and outwardly covered with particles of earth. It generally lies so near the surface that no "neck" or emergence tube is necessary.

The pupa itself is very similar to others of this genus. Bright yellow when first formed, it soon darkens to a mahogany brown. A day or two before emergence the silvery stripe in the forewing becomes plainly visible through the covering. The

pupa is 9.0 millimeters long and 2.0 millimeters wide. The caudal process is flattened into a broadly triangular plate with sharp margins, its acute tip bent slightly ventrad. Close to the tip of this plate below are two slender bristles with upturned ends, while above, more widely spaced and standing about halfway from the tip to the basal angles of the plate, are two shorter, smaller bristles with down-turned ends. Beneath, the process is flattened but not excavated.

The data as to the duration of the pupa stage are included in Table III. It varies somewhat, depending on the temperature, in the writer's records ranging from 9 to 18 days. The last, however, is very unusual, and the average of all the records puts it at 10.65 days, which is much more nearly correct. Ten days may be taken as the usual duration of this stage during the growing season.

## SYSTEMATIC RELATIONSHIPS

*Crambus praefectellus* is closely similar to *C. leachellus* in structure as in wing markings. The male genitalia differ in that in the former species the cucullus of the harpe is narrower and somewhat more falcate, the free costal margin is shorter and more highly chitinized, and the cornutus of the aedoeagus is smaller. *C. unistriatellus* also undoubtedly belongs to this group. Its harpes and uncus are very similar, but the aedoeagus differs somewhat in its armament. Another species, as yet not definitely determined but externally very similar to *C. leachellus*, has genitalia which place it in this group, though it is certainly specifically distinct from any of the other members. *C. quinquareatus* (considered by Felt as *C. hastiferellus* Walk.) is placed in this group by Felt (*4, p. 85*), but for want of more certain synonymy its position is not discussed.

## SUMMARY

*Crambus praefectellus* is an American species widely distributed throughout the eastern half of the United States. While not often injurious, it has shown itself capable of causing serious damage.

It breeds continuously throughout the growing season. The generations are not distinct, but rearing records indicate that three generations per year is the usual number.

The moths are not often abundant. They prefer waste or weedy land and are seldom found in clean grasslands. The larvæ are readily reared on grasses. Winter is passed by the partly grown or mature larvæ. The moths from the mature larvæ emerge early in the spring and are the first Crambus moths to appear.

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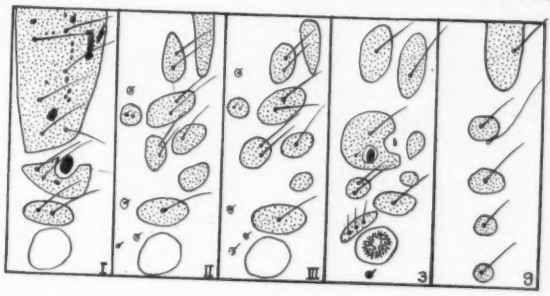
## PLATE 1

*Crambus praefectellus:*

A.—Setal map of larva showing arrangement of pinacula and setæ on the three thoracic and third and ninth abdominal segments.
B.—Male genitalia: Harpes.
C.—Male genitalia: Aedoeagus.
D.—Male genitalia: Tegumen and uncus.
E.—Male antennal segment (twenty-fifth). Greatly enlarged.
F.—Female antennal segment (twenty-fifth). Greatly enlarged.
G.—Female genitalia: Valve.
H.—Polar area of egg. Greatly enlarged.

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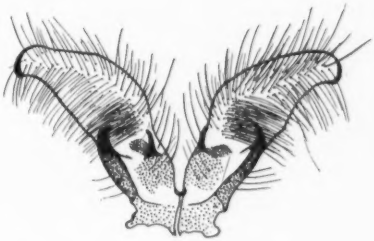

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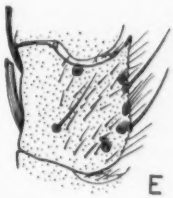

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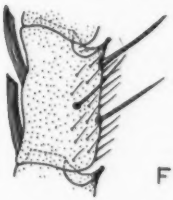

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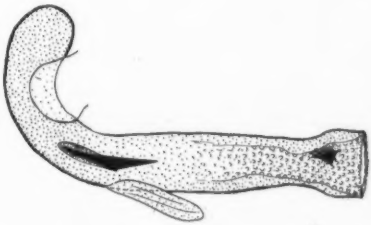

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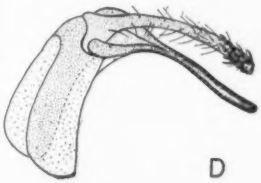

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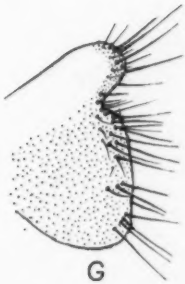

G

# MOVEMENT OF SOIL MOISTURE FROM SMALL CAPILLARIES TO THE LARGE CAPILLARIES OF THE SOIL UPON FREEZING[1]

By GEORGE JOHN BOUYOUCOS

*Research Professor in Soils, Michigan Agricultural Experiment Station*

## INTRODUCTION

In conducting various studies upon the temperature[2] and freezing-point lowering[3] of soils, many evidences have been obtained which indicate that the moisture of the soil upon freezing moves from the small capillaries, and probably also from around the particles as thick films, into the larger capillaries of the soil. This accumulation of the soil moisture in the large capillaries takes place especially when the moisture content of the soil is low. When the moisture content is high and under proper conditions the water accumulates as ice capillary columns at the top of the soil surfaces. These results are of considerable interest and importance as they bear on many soil-water relationships, such as the unfree water, available water, freezing-point lowering, vapor-pressure lowering, rate of evaporation, capillary movement, osmotic pressure, aud perhaps others.

## EXPERIMENTAL EVIDENCES

In measuring the freezing-point lowering of soils at low moisture content, it was found that upon repeated freezing and thawing the lowering of the freezing point diminished greatly. But upon stirring the soil, even gently, the freezing-point lowering would go back to the original magnitude. If the soil was again subjected to alternate freezing and thawing, the freezing-point lowering would again diminish, and if it was stirred the lowering of the freezing point would become as before. This process could be continued almost indefinitely with practically the same results. Allowing the soil to stand after it was frozen and thawed several times tended to have somewhat the same effect as stirring, that is, it tended to restore the freezing-point depression to the original magnitude. In Table I the results in the case of two soils which will serve as typical examples of the phenomena in question are presented.

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[1] Accepted for publication Aug. 15, 1922.

[2] BOUYOUCOS, George J. SOIL TEMPERATURE. Mich. Agr. Exp. Sta. Tech. Bul. 26, 133 p. 1916.

[3] BOUYOUCOS, George J. and MCCOOL, M. M. FURTHER STUDIES ON THE FREEZING POINT LOWERING OF SOILS. Mich. Agr. Exp. Sta. Tech. Bul. 31, 51 p., 1 fig. 1916. Bibliographical footnotes.

TABLE 1.—*Effect of alternate freezing, thawing, stirring, and standing on the freezing-point depression of soils*

WISCONSIN SUPERIOR CLAY (20 GM. SOIL AND 4.5 CC. WATER).

| Treatment. | Freezing-point depression. |
|---|---|
| | °C. |
| First freezing | 1.115 |
| Second freezing | .955 |
| Third freezing | .645 |
| Fourth freezing | .620 |
| Stirred gently in tube with rod | 1.215 |
| Cooled at −10° C. after stirring | .680 |
| Stirred gently in tube with rod | 1.215 |
| Cooled at −10° C. after stirring | .700 |
| After standing one day in room temperature | .787 |
| Cooled at −10° C | .701 |

MICHIGAN SILT LOAM (20 GM. SOIL AND 3 CC. WATER).

| | |
|---|---|
| First freezing | 0.880 |
| Cooled at −10° C | .460 |
| Stirred gently in tube with rod | .790 |
| Kept at −10° for several hours after stirring | .360 |
| Stirred gently in tube with rod | .785 |
| Cooled at −10° C. after stirring | .420 |
| Stood in room temperature after the last reading for 10 days | .600 |
| Cooled at −10° C | .360 |

BLACK CLAY LOAM (20 GM. SOIL AND 4 CC. WATER).

| | |
|---|---|
| First freezing | 0.760 |
| Cooled at −10° | .400 |
| Cooled at −10° for several hours | .270 |
| Stood two days at room temperature | .430 |
| Cooled at −10° | .322 |
| Stirred gently in tube with rod | .760 |
| Cooled at −10° after stirring | .450 |
| Stirred gently in tube with rod | .765 |

An examination of the results indicated in Table I shows the great influence that different treatments have upon the freezing-point depression of soils at low moisture contents. In the case of the Wisconsin superior clay, for instance, the freezing-point lowering diminished by alternate freezing and thawing from 1.115° to 0.620° C. at the fourth freezing. Upon stirring the soil mass with a rod in the tube, the freezing-point depression increased from 0.620° to 1.215°. When the soil was kept at a temperature of −10° for few minutes the depression fell from 1.215° to 0.680°. As the soil was stirred again the depression rose from 0.680 to 1.215 as before. By leaving the soil to stand for one day at room temperature, after the depression was diminished by repeated freezing, the depression rose from 0.700° to 0.787°. It will be noted that in some cases stirring increases the freezing-point depression even to more than the original extent.

Results of the same type are also obtained on natural field soils. In Table II are shown the results with a silt loam taken from the field when the moisture content was moderately low and the soil had a crumb structure.

TABLE II.—*Effect of alternate freezing, thawing, stirring, and standing on the freezing-point depression of a field soil (silt loam)*

| Treatment. | Freezing-point depression. |
|---|---|
| | °C. |
| First freezing | 1.150 |
| Second freezing | .870 |
| Stirred gently in tube | 1.230 |
| Frozen once after stirring | .880 |
| Cooled at −10° C. for several hours | .680 |

These results, obtained from the natural soil, agree perfectly with and confirm those from the artificially moistened soil. The question is, therefore, what factor is responsible for the great influence on the freezing-point depression of alternate freezing, thawing, stirring, and standing of the soils?

Before the effect of stirring upon the freezing-point depression was discovered, it was thought that the diminution of the lowering of the freezing point was due, at least partly, to the coagulation of the colloids upon freezing, and to the consequent liberation of unfree water from the colloids. The hypothesis [4] advanced was that the unfree water had a lower concentration than the free water, and upon its liberation it went to dilute the free water and thereby increased its freezing-point lowering. In view of the effect of stirring, however, this coagulation theory does not appear to afford the whole explanation for the phenomenon.

The most logical and plausible explanation that now presents itself is the assumption that, upon freezing, the moisture in the small capillaries and that surrounding the particles as thick films accumulates in the larger capillaries of the soil by the force of crystallization. In other words, the water in the larger capillaries, upon freezing, draws upon itself by the force of crystallization the water from the finer or smaller capillaries and films around the soil particles, and grows at their expense. Thus the water in the large capillaries affects the freezing-point depression differently from that in the small capillaries. How this is accomplished will be discussed later. Meanwhile, further evidence is here offered indicating that water moves from the small to the large capillaries upon freezing.

When a soil with low moisture content is frozen, small droplets or particles of ice are formed at different places in the soil mass. These ice particles or droplets occur in soils both under laboratory and field conditions and can be seen very readily and distinctly even with the naked eye. Upon close examination it is found that they occur mainly in the most porous places or in the largest capillary spaces between the soil particles.

However, when the soil is very moist and the freezing process is not too rapid, the moisture freezes at the surface of the soil in the form of

[4] BOUYOUCOS, George J. THE CONCENTRATION OF THE SOIL SOLUTION AROUND THE SOIL PARTICLES. *In* Soil Sci., v. 11, p. 131–138. 1921.

ice capillary columns, or long needle-like crystals. The force of crystallization seems to pull the water from below and bring it to the surface, where it freezes into these massive ice capillary columns or compact needle-like crystals. In Plate I a typical example of this phenomenon is shown. This picture was taken on a muck soil during the latter part of November, when the soil temperature below the surface was still considerably above the freezing point. The ice capillary columns would be formed at the surface of the soil without penetrating the lower depths, growing upward as straight needles or thin capillary tubes massed together. The growth seems to take place at the lower end and push the entire column upward, as the capillary tubes are elongated from below. The ice column shown in Plate I is about 4 inches thick, and was formed during three nights. The formation for each night is indicated by the lines or layers seen in the column.

As previously stated, the water which went to make this 4-inch column of ice came from the capillary water of the soil at a lower depth, and was brought to the surface by the pull or force of crystallization. From these results it is easily understood that it is possible for the moisture to move from the finer capillaries, and from around the particles as films, to the larger capillaries of a soil short of saturation. This phenomenon of the transference of moisture from the smaller to the larger capillaries upon freezing is somewhat analogous to another phenomenon—the tendency of small drops of liquid to unite into a single drop, which is accomplished either by actual contact or by the transference of vapor from the smaller to the larger drops.

In referring again to the effect on the freezing-point depression, another question arises: Why should the water in the large capillaries affect the freezing-point depression differently from that in the finer capillaries?

These differences can be easily explained if the hypothesis[5] previously advanced is correct. This hypothesis assumes that the solution immediately around the soil particles and in the very fine capillary spaces is less concentrated than the mass of the solution. This assumption which accords with the results presented in this paper, holds that the force of crystallization tends to draw the moisture from the finer capillaries and from around the particles as films into the larger capillaries. It is readily seen that during freezing and thawing the dilute solution from the finer capillaries and the films from around the particles go to dilute the solution in the larger capillaries or the mass of the solution. The consequence is that the original freezing-point depression is diminished. When the soil mass is stirred the moisture is again redistributed and readjusted and the freezing-point depression becomes as before.

If the hypothesis of the difference in concentration between solution in mass and that in the finer capillaries and around the soil particles is true, the above explanation is probably the correct one. But Parker [6] has published results to show that when the water is reduced to film or capillary form it has a decided physical effect upon the freezing-point depression. If his claim is true the explanation that immediately suggests itself is that the water in the larger capillaries has less physical

[5] Bouyoucos, George J. Op cit.

[6] Parker, F. W. Methods of studying the concentration and composition of the soil solution. *In* Soil Sci., v. 12, p. 209–232. 1921. References, p. 231–232.

effect upon the freezing-point depression than that in the finer capillaries and around the particles as thin films.

It can not be definitely stated now which of these two explanations is correct. If the latter one is true the position or relative distribution of the capillary water as between the finer and larger capillaries affects not only the freezing-point depression but also such factors as osmotic pressure, vapor pressure lowering, rate of evaporation, available water, etc.

Since any treatment of the soil (stirring, breaking up the compound particles or crumbs, freezing and thawing, addition of flocculent or deflocculent agents) would alter the position of the capillary water as between the small and large capillaries and films, and would have a pronounced effect upon the above factors, their determination could not be absolute. Such determinations, for instance, as the vapor-pressure lowering of soils as reported recently by Thomas,[7] could not be considered absolute. If stirring, freezing, etc., affect the freezing-point depression, they will certainly also affect the vapor pressure lowering. The same would be true for several of the other factors.

## SUMMARY

Evidence is presented which shows that when a soil short of saturation is frozen, the force of crystallization tends to draw the moisture from the small capillaries and from around the particles as thick films, into the larger capillaries.

However, when the soil is wet or saturated, under proper conditions the moisture freezes at the surface of the soil and forms capillary ice columns or thin needle-like crystals. The force of crystallization draws the water from below, which freezes at the lower end of the column and pushes the entire column upward.

The relative distribution of the capillary water is between the finer and the larger capillaries and may have a very appreciable effect upon such factors as freezing-point depression, vapor-pressure lowering, osmotic pressure, and rate of evaporation. Any treatment of the soil which will alter the relative distribution of the soil moisture as between the finer and larger capillaries would seem to affect these factors.

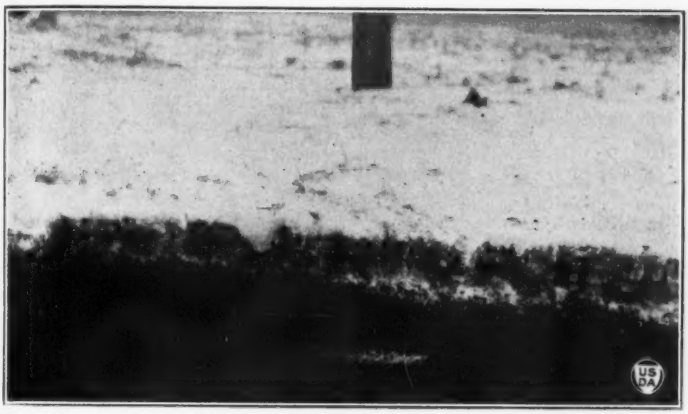
[7] THOMAS, Moyer D. AQUEOUS VAPOR PRESSURE OF SOILS. *In* Soil Sci., v. 11, p. 409-434, 5 fig. 1921. References, p. 433-434.

## PLATE 1

**Column of ice composed of thin capillary tubes or needlelike crystals formed at the surface of a wet muck. The force of crystallization brings the capillary water to the surface and, as it freezes into these massive capillary tubes, the whole column is pushed upward as the growth takes place at the lower end of the whole.**

Movement of Soil Moisture upon Freezing

PLATE I



# NUTRITIVE VALUE OF THE GEORGIA VELVET BEAN (STIZILOBIUM DEERINGIANUM)[1]

By J. W. READ, *Head of Department of Agricultural Chemistry*, and BARNETT SURE, *Associate Professor of Agricultural Chemistry, Arkansas Agricultural College*

This paper is the third (*6,5*)[2] of a series of investigations covering the nutritive value of the Georgia velvet bean as originally planned and outlined by the senior author. It discusses the supplementary relationship of whole and skimmed milk to the hulled seed and the whole plant, and of the leaf and the hulls to the seed. Subsequent papers will deal with the biological analysis of velvet bean meal (ground pods and beans), the dietary deficiencies of some practical rations including the velvet bean as a certain portion of the diet, and the biological evaluation of the whole plant. These investigations are in progress.

In the authors' first paper (*6*) it was shown that the seed of the Georgia velvet bean, unlike most seeds so far studied, has a great abundance of vitamine A, but is deficient in salts, in quality of protein, and in vitamine B; that the raw mature seed is toxic to rats, and that the autoclaved seed, when it is the sole source of food, is inadequate even for maintenance. It was also shown that a ration composed of 60 per cent cooked seed (tough seed coats excluded) and 40 per cent dextrin served for maintenance for eight weeks. During the first six weeks all of the animals were apparently in an excellent state of nutrition, but immediately following this period their coats became rough, with some loss of hair. It was evident that a dangerous point in the maintenance curve had been reached and the ration was changed by the addition of a liberal supply of whole milk. On the modified ration all of the animals made even better than normal growth and three generations were reared successfully. Since the authors' previous work indicated that the seed is rich in the A vitamine, experiments employing skimmed milk instead of whole milk and replacing dextrin by starch were also introduced.

Recently Mattill and Conklin published a paper (*2*) which showed that milk, even when given in the dried form to furnish enough of the solids and fortified with iron citrate, permits no rearing of the young, although it does promote considerable growth. On a ration composed of 99 parts dried milk and 1 part yeast they secured normal growth and partially successful reproduction. For this reason, these authors suggest the possibility of yeast supplying something unique in the ration. On the basis of the results secured on their various milk diet, they also express the opinion that milk may be both quantitatively and qualitatively inadequate for adolescent growth and reproduction, especially in the female, and that it may even contain substances inhibitory to growth in

[1] Accepted for publication Aug. 21, 1922. Published by courtesy of the American Chemical Society; paper read at New York meeting, September, 1921.

[2] Reference is made made by number (italic) to "Literature cited," p. 440.

the third or mature growth cycle. In following up this work, Mattill (*1*) has recently reported that dilution of whole milk powder with lard, starch, and salts in varying proportions did not prevent failure of adolescent growth and reproductive ability in female rats, If, however, a small amount of yeast was added to the milk rations the females cast litters regularly and repeatedly, but the young soon died.

Since the completion of our experiments, a paper by Sherman, Rouse, Allen, and Woods (*4*) has appeared. Using the rat as the experimental animal, they secured practically the normal rate of growth for both sexes on a mixture of equal weights of bread and milk in which white bread furnished four-fifths and milk only one-fifth of the total calories (or a corresponding mixture of dry bread or flour and whole milk powder), but reproduction failed on this simple diet. If ground whole wheat instead of white bread or patent flour furnished four-fifths of the calories in the above ration, young were successfully suckled, though at a considerable loss of weight on the part of the mother, grew to maturity at somewhat less than the average rate, and in several cases have produced and successfully suckled young of the third generation. When the proportion of milk in the diet constituted about two-fifths of the total calories of

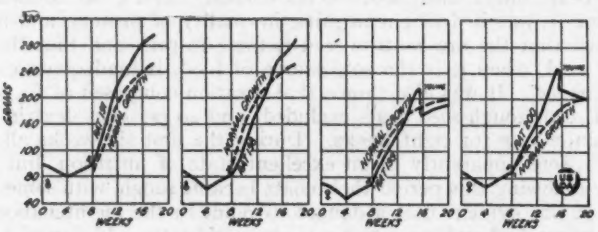



FIG. 1.—Velvet bean, 60 per cent; dextrin, 40 per cent. At point *a* a liberal supply of whole milk was added to the ration. Dotted lines represent normal curves of growth. Y=young.

the food mixture, the rest of which was ground whole wheat, the young were suckled without undue loss of the mother's weight, and these young have grown normally, as have also the young of the third generation. The inference to be drawn from their experiments is that wheat contains some substance or substances deficient in milk which are necessary for reproduction.

In the authors' experiments to determine the supplementary value of hulls (by which is meant the tough outer seed coat) to the seed, these hulls were dried and incorporated into the seed portion of the rations in the same amount as they form a natural part of the seed. The ground seed (hulls excluded) was autoclaved before feeding, but the leaf and hulls were added to the diets in their natural state.

EXPERIMENT I, LOT L.—(Charted in fig. 1.) This ration was started with 60 per cent cooked velvet bean seed (hulled) and 40 per cent dextrin. During the first six weeks of experimentation, the animals were all in a perfect maintenance condition, after which period they began to show characteristic signs of malnutrition, as evidenced by the roughness of their coat, lack of energy, loss of hair, etc. At point *a* a liberal supply of whole milk was added to the ration. From that period a little better than normal growth was obtained. Rat 200 gave birth to eight young

but was allowed only four to rear, in order not to overtax her mammary capacity. These four young were successfully reared to weaning age.

EXPERIMENT II, LOT L.—(Charted in fig. 2.) This experiment shows the successful normal growth of the young of rat 200 to maturity. These animals were permitted to interbreed, and it will be noted that rat 471 reared the third generation successfully. Rat 200 was then bred to one of her sons and successfully reared all the eight young which she brought forth at birth. (Not shown on fig. 2.) Our efforts to substitute the uncooked seed for the cooked met with failure, due evidently to the toxic principle in the raw seed.

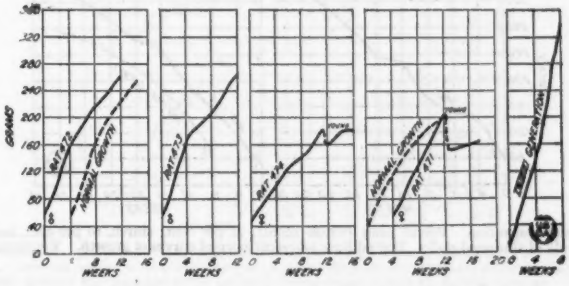



FIG. 2.—Second generation. Velvet bean, 60 per cent; dextrin, 40 per cent, plus a liberal supply of whole milk. Dotted lines represent normal curves of growth. Y=young.

EXPERIMENT III, LOT CXIII.—(Charted in fig. 3.) On a ration composed of 40 per cent velvet bean hay (finely ground whole plant), 60 per cent starch, and a liberal supply of skimmed milk, rat 454 successfully reared the four young to which she gave birth.

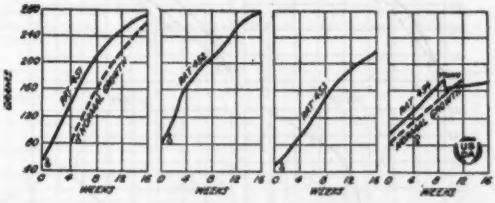



FIG. 3.—Velvet bean (whole plant), 40 per cent; starch, 60 per cent; and a liberal supply of skimmed milk Dotted lines represent normal curves of growth. Y=young.

EXPERIMENTS IV, V, LOT CXIII.—(Charted in fig. 4 and 5.) This experiment showed that quite satisfactory growth was secured through the second and third generations on this simple and monotonous ration of whole plant 40, starch 60, and a liberal supply of skimmed milk. We attribute the poorer showing of the animals on Figure 4 to hot weather and less consumption of milk due to rapid souring. The whole plant and starch mixture was readily eaten by all of our animals on this ration.

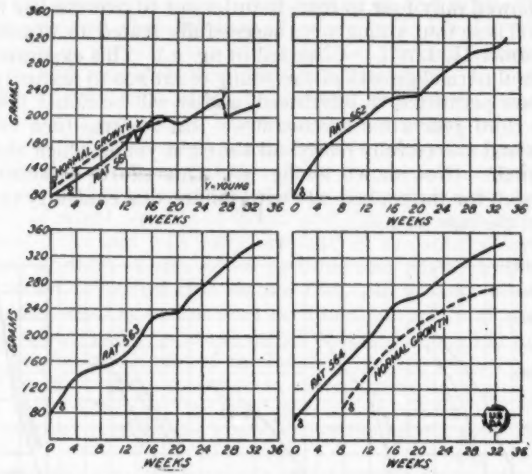



FIG. 4.—Second generation. Velvet bean (whole plant), 40 per cent; starch, 60 per cent, and a liberal supply of skimmed milk. Dotted lines represent normal curves of growth. Y=young.

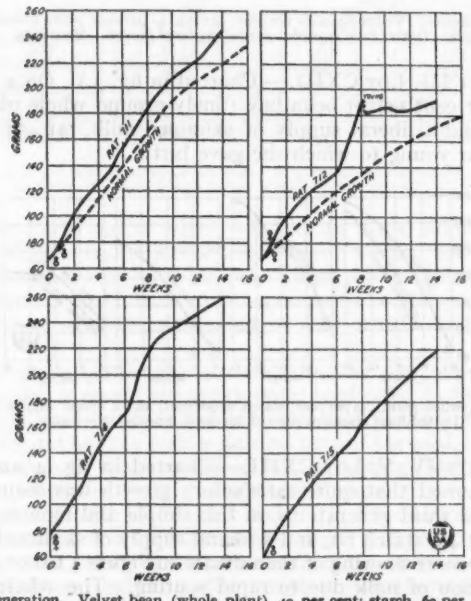



FIG. 5.—Third generation. Velvet bean (whole plant), 40 per cent; starch, 60 per cent, and a liberal supply of skimmed milk. Dotted lines represent normal curves of growth.

EXPERIMENT VI, LOT LXXVIII.—(Charted in fig. 6.) This experiment showed that the velvet-bean hulls offer no supplementing value to the deficient proteins in the seed, neither was there any appreciable change in the character of growth when, at point *a*, 21 per cent of dextrin was replaced by 21 per cent velvet-bean leaves.

EXPERIMENT VII, LOT LXXVI.—(Charted in fig. 7.) It is apparent from this experiment that the hulls in the velvet bean, unlike those in

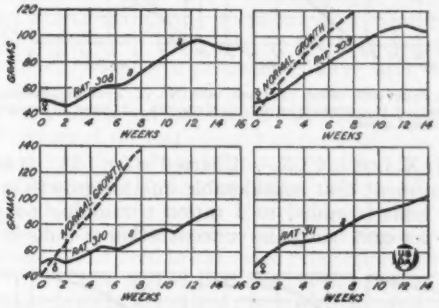



FIG. 6.—Velvet bean, 53 per cent; hulls, 7 per cent; salts (No. 32), 4 per cent; butter fat, 5 per cent; dextrin, 21 per cent. Dextrin carried alcoholic extract of 10 grams ether-extracted wheat embryo. At point *a* the 21 per cent dextrin was replaced by 21 per cent velvet bean leaves to furnish protein. Dotted lines represent normal curves of growth.

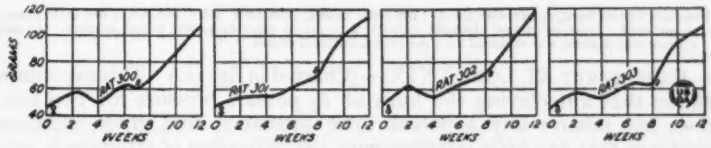



FIG. 7.—Velvet bean, 53 per cent; hulls, 7 per cent; salts (No. 32), 4 per cent; butter fat, 5 per cent; casein, 5 per cent; dextrin, 26 per cent. At point *a* the 26 per cent dextrin was substituted by 26 per cent velvet-bean leaves to furnish the water-soluble vitamine.

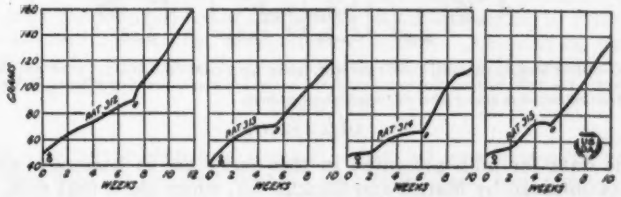



FIG. 8.—Velvet bean, 53 per cent; hulls, 7 per cent; butter fat, 5 per cent; casein, 5 per cent; dextrin, 30 per cent. At point *a* 10 per cent dextrin was replaced by 10 per cent velvet bean leaves to furnish salts. Dextrin carried alcoholic extract of 10 grams ether-extracted wheat embryo.

the rice kernel, are not carriers of the B vitamine. When, however, at point *a* 26 per cent dextrin was replaced by an equivalent amount of velvet-bean leaf a striking change in the character of growth was obtained in all cases.

EXPERIMENT VIII, LOT LXXIX.—(Charted in fig. 8.) The hulls offer very little supplementing value to the seed in so far as salts are concerned, but as low as a 10 per cent concentration of velvet-bean leaves furnishes a very satisfactory source of salts when added to 53 per cent of the seed.

EXPERIMENT IX, LOT LXVII.—(Charted in fig. 9.) This experiment showed that when the velvet-bean seed serves as the only source of the A vitamine fed at a 60 per cent level very good growth is secured.

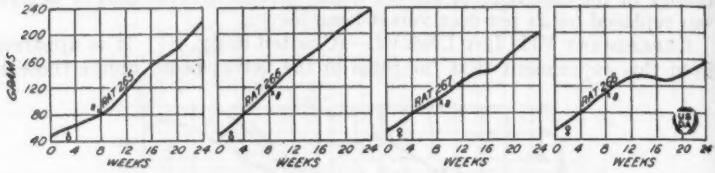



FIG. 9.—Velvet bean, 60 per cent; casein, 5 per cent; salts (No. 32), 4 per cent; dextrin, 31 per cent. Dextrin carried alcoholic extract of 10 grams ether-extracted embryo. At point *a* 4 per cent dextrin was replaced by 4 per cent additional casein.

EXPERIMENT X, LOT LXXX.—(Charted in fig. 10.) It is quite apparent from this experiment that considerable inferior growth is obtained when 7 per cent of hulls is added to a ration containing 60 per cent of the hulled seed, 7 per cent being the concentration of hulls in the whole seed.

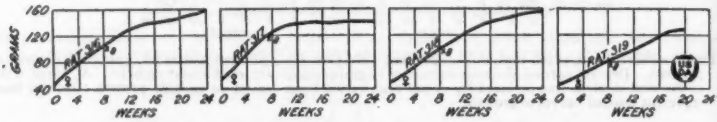



FIG. 10.—Velvet bean, 53 per cent; hulls, 7 per cent; casein, 5 per cent; salts (No. 32), 4 per cent; dextrin, 32 per cent. Dextrin carried alcoholic extract of 10 grams ether-extracted wheat embryo. At point *a* 4 per cent dextrin was replaced by 4 per cent additional casein.

EXPERIMENT XI, LOT CXXIX.—(Charted in fig. 11.) This experiment shows that autoclaving the hulls at 15 pounds pressure for two hours does not remove any apparent toxic substance, and gives additional evidence that the hulls interfere with the utilization of vitamine A.

FIG. 11.—Velvet bean, 53 per cent; hulls, 7 per cent; casein, 9 per cent; salts (No. 32), 4 per cent; dextrin, 27 per cent. The hulls in this ration were autoclaved for two hours at 15 pounds pressure. Dextrin carried alcoholic extract of 10 grams ether-extracted wheat embryo.

## DISCUSSION

The data for milk presented in this paper are in harmony with the results obtained by Mattill and Conklin (*2*), which show that milk alone, while it allows a certain amount of growth to take place, is inadequate for reproduction in the albino rat. The attempts made by the authors to furnish liquid milk and dextrin with a liberal supply of distilled water resulted in complete failure in most cases, and in only a few cases was some growth obtained. It is quite evident then that milk is lacking in one or more dietary essentials indispensable for satisfactory growth and for reproduction.

From a consideration of the various experiments on nutritive valu of milk (reported in the literature) and in so far as Osborne and Mendel (*3*) have shown that the amino-acid requirements for growth and for maintenance are different, it seems to the authors that the difficulty may possibly be found with the milk proteins.

It has already been stated that Sherman, Rouse, Allen, and Woods (*4*) found that wheat in certain proportions supplemented milk to the extent of enabling mother rats to rear their young successfully, and on these diets they secured normal nutrition through three generations. The authors found in an extensive study of the nutritive value of the Georgia velvet bean that the velvet bean seed, a legume, supplements whole milk to the extent that three generations have been secured, all of the animals having performed even a little better than normal in their rate of growth. Even on such a simple and poorly constituted physical diet as that composed of 40 per cent velvet bean hay, 60 per cent starch, and a liberal supply of skimmed milk, three generations have been successfully produced by the authors.

The leaf of the Georgia velvet bean is an efficient carrier of salts and vitamine B. Portions of the leaf (10 and 26 per cent) added to 53 per cent of the seed improved the nature of growth considerably from the standpoint of both salts and the B vitamine, respectively. The hulls, however, seem to have no biological value. The authors' results show, however, that they interfere with the utilization of the A vitamine when added to a 60 per cent intake of the seed in the same proportion in which they occur in the seed. It might be argued that the inferior growth obtained by the addition of 7 per cent hulls could be due to a reduction of the total plane of intake from 60 to 53 per cent. However, such is not the case, because comparable growth was obtained when only 20 per cent of the seed, without the hulls, served as the only source of vitamine A.

The composition of velvet bean hulls, as reported by Tracy and Coe (*7, p. 31*), is as follows:

| | Per cent |
|---|---|
| Ash | 6.0 |
| Crude protein | 5.7 |
| Fiber | 30.0 |
| Nitrogen-free extract | 57.0 |
| Fat | 1.1 |

It will be noted from the above table that the hulls are very abundant in fiber, or indigestible celluloses. It seems reasonable, therefore, to suggest that the interference of the hulls with the utilization of vitamine A may be attributed to their indigestible celluloses. Autoclaving the hulls for two hours at 15 pounds pressure did not change the nature of their disturbing effect.

## SUMMARY

(1) The velvet-bean seed (cooked) when fed at a level of 60 per cent together with 40 per cent dextrin, and velvet-bean hay (whole plant) when fed at a 40 per cent plane of intake together with 60 per cent starch, supplement milk in a manner satisfactory for growth and reproduction.

(2) The Georgia velvet-bean leaf is quite abundant in the B vitamine and contains salts of excellent biological value.

(3) The hulls have no supplementary value, and interfere with the utilization of the A vitamine in the seed. Autoclaving for two hours at 15 pounds pressure did not change their disturbing effect.

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